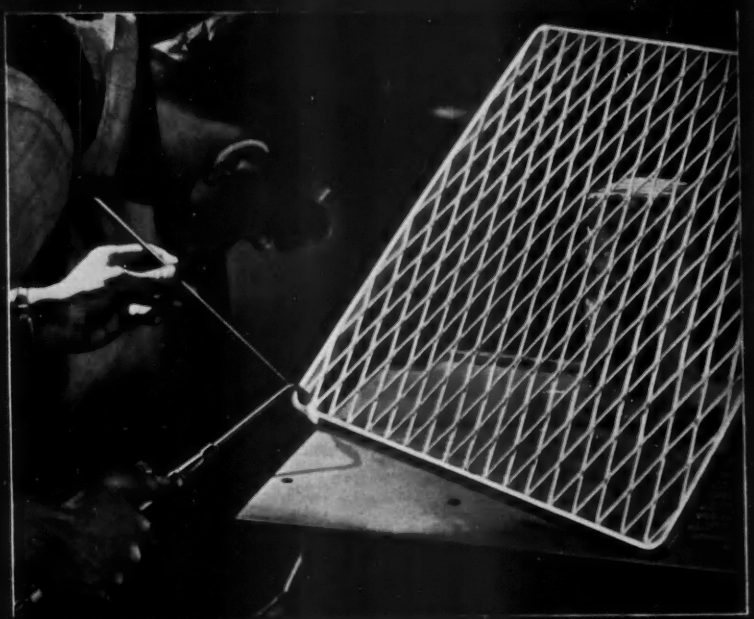
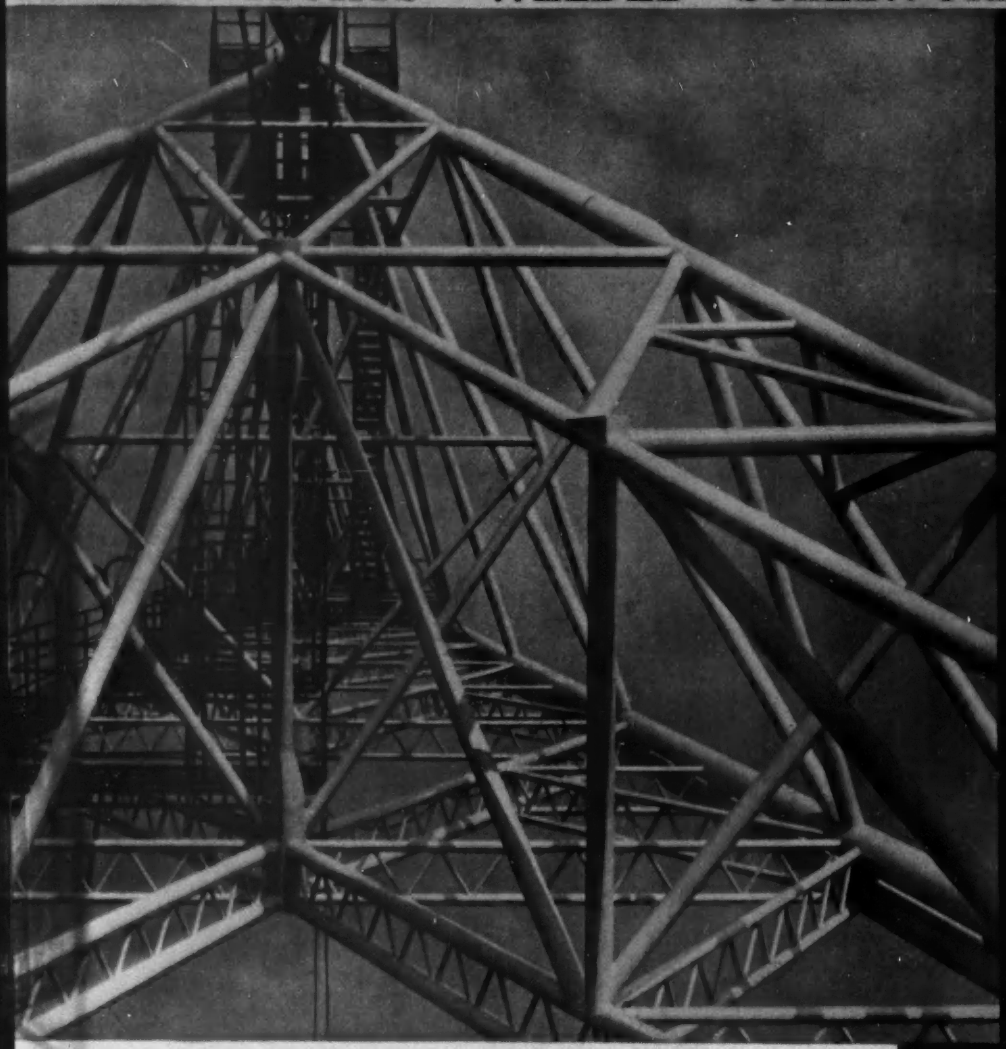


'TUBEWRIGHTS' WELDED STEELWORK



Advances in design and technique

THE GREAT JIB

for the Rapier W.1400 Dragline.

The largest in the world, length 282 feet.

Minimum slewing radius 260 feet.

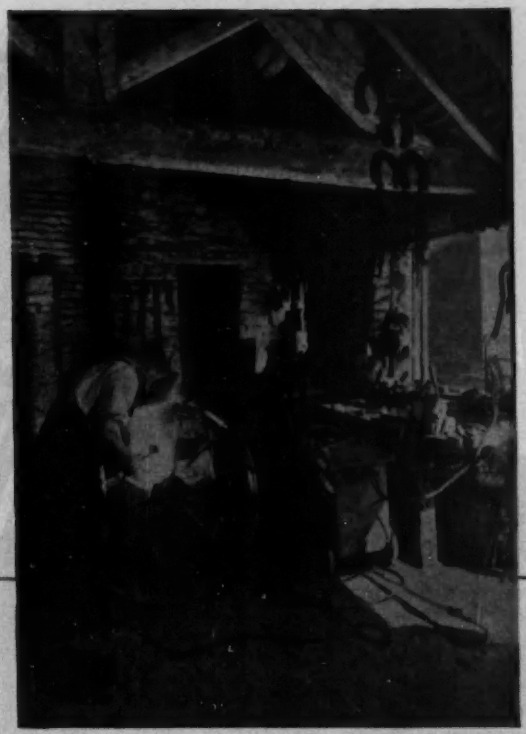
Bucket capacity 20 cubic yards.

TUBEWRIGHTS LTD.

EGGINTON HOUSE, 25 BUCKINGHAM GATE, LONDON, S.W.1. TELEPHONE: VICTORIA 0451

A subsidiary of Stewarts and Lloyds Limited

Portable welding plant for repair work



'ENGLISH ELECTRIC'
welding equipment

'ENGLISH ELECTRIC', pioneers of A.C. arc-welding in Britain, have developed a wide range of both single and multi-operator units to meet all welding requirements in industry.

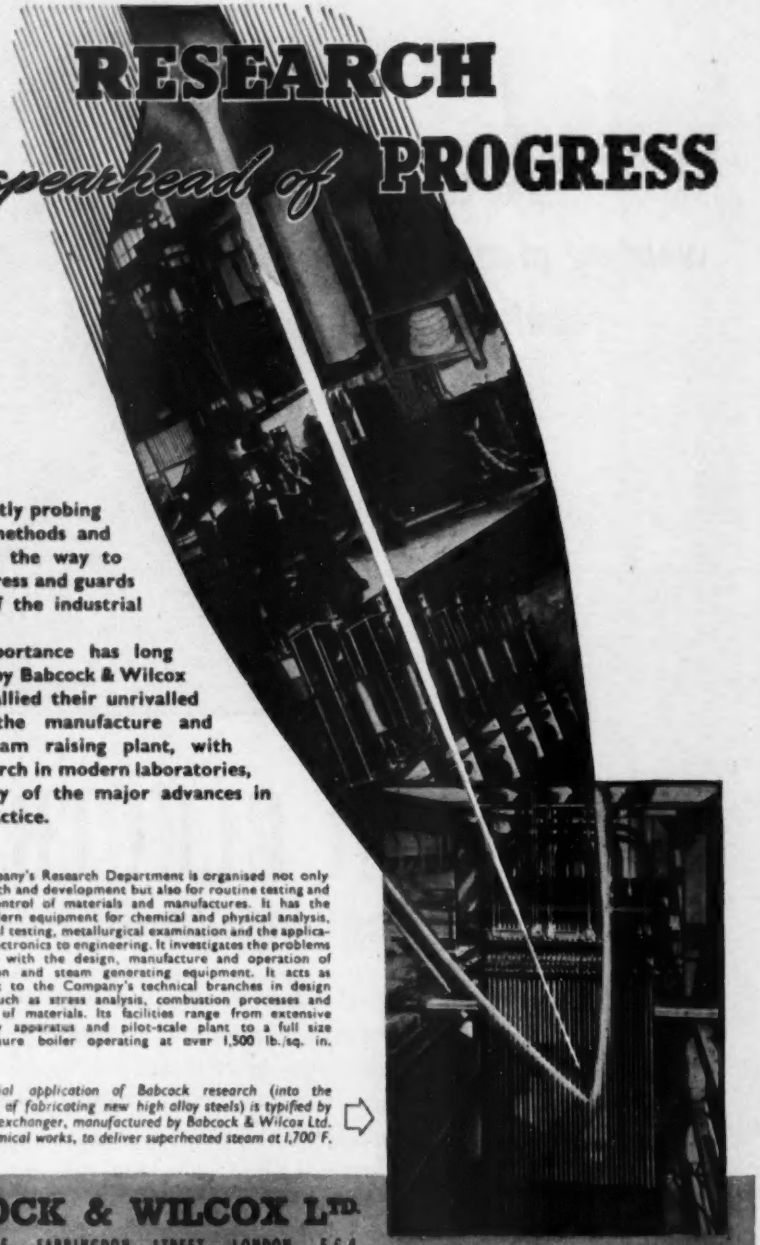
Among the 'ENGLISH ELECTRIC' standard single-operator portable units, is type F.W.C. 250 for welding up to a maximum of 250 amperes. This compact unit is ideal for a variety of situations, ranging from the village smithy specialising in the overhaul of agricultural machinery to the larger works and garages where jobs are widely diverse in both location and type.

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2
Welding Equipment Section, Liverpool
WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL

WE.3

RESEARCH

the spearhead of PROGRESS



Research, constantly probing to find better methods and materials, points the way to engineering progress and guards the reputation of the industrial product.
Its primary importance has long been recognised by Babcock & Wilcox Ltd., who have allied their unrivalled experience in the manufacture and operation of steam raising plant, with continuous research in modern laboratories, to produce many of the major advances in steam raising practice.

The Company's Research Department is organised not only for research and development but also for routine testing and quality control of materials and manufactures. It has the most modern equipment for chemical and physical analysis, mechanical testing, metallurgical examination and the application of electronics to engineering. It investigates the problems associated with the design, manufacture and operation of combustion and steam generating equipment. It acts as consultant to the Company's technical branches in design matters such as stress analysis, combustion processes and selection of materials. Its facilities range from extensive laboratory apparatus and pilot-scale plant to a full size high-pressure boiler operating at over 1,500 lb./sq. in.

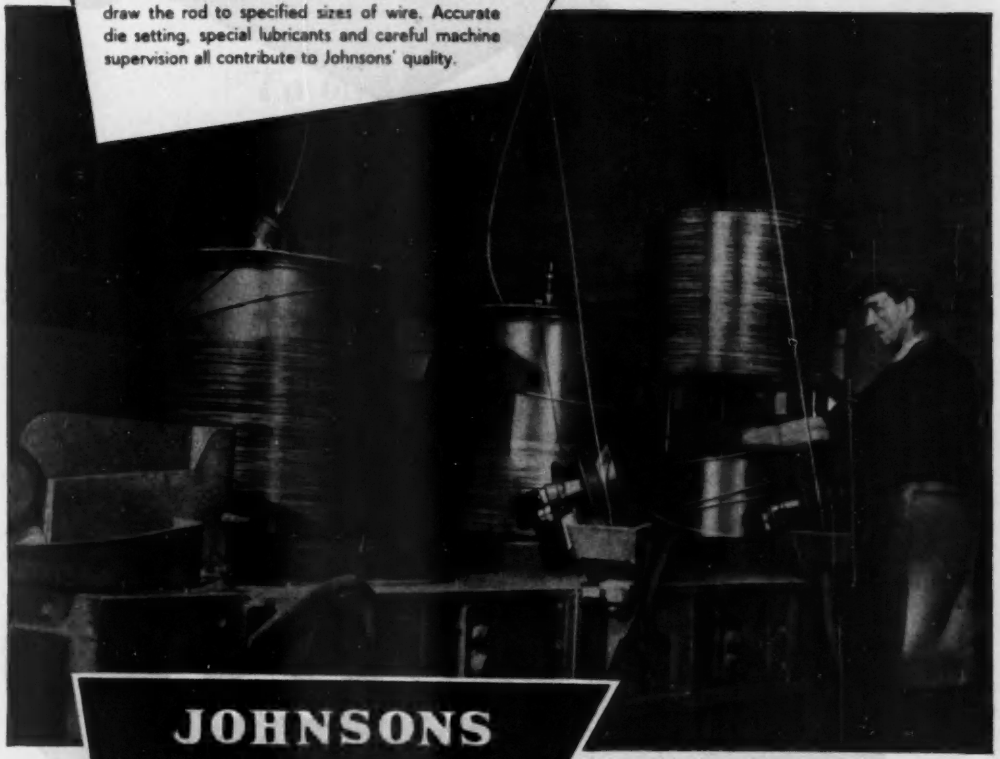
Commercial application of Babcock research (into the technique of fabricating new high alloy steels) is typified by this heat exchanger, manufactured by Babcock & Wilcox Ltd. for a chemical works, to deliver superheated steam at 1,700 F.

BABCOCK & WILCOX LTD.
BABCOCK HOUSE, FARRINGDON STREET, LONDON, E.C.4.

How much is your reputation worth?

It's worth just as much as the quality of the product you turn out! And for that reason it's wise to choose well when you buy welding wire. Make certain it comes from a firm with experience who really understand your needs. Then you are assured of a really first-class product correctly made to exact analytical requirements. In other words don't just buy welding wire . . . . . buy Johnsons!

WIRE DRAWING. Modern continuous machines draw the rod to specified sizes of wire. Accurate die setting, special lubricants and careful machine supervision all contribute to Johnsons' quality.



JOHNSONS WIRE . . . *FOR THE WELDING INDUSTRY*

RICHARD JOHNSON & NEPHEW LTD., FORGE LANE, MANCHESTER, 11

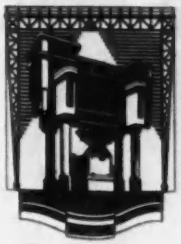
STRONG,
COMPACT,
RELIABLE UNITS,
SCIENTIFICALLY
DESIGNED.

Single Operator Welding Sets

by G.E.C.

Send for Booklet P9556

THE GENERAL ELECTRIC CO., LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2



"To build . . is the noblest art of all the arts"

Longfellow

BRAITHWAITE & CO

ENGINEERS LIMITED

Bridge & Constructional Engineers, Civil Engineers & Contractors

London Office: *Telephone: WHitehall 3993*

DORLAND HOUSE · REGENT STREET · LONDON · SW1

Packed with
EXPERIENCE–
—the experience of many years of welding in our own shops
The electrodes we sell are the electrodes we use
Metrovick
WELDING ELECTRODES

METROPOLITAN-VICKERS ELECTRICAL CO. LTD.

TRAFFORD PARK, MANCHESTER 17

Member of the A.E.I. group of companies

P/8901

APPLEBY PLATES for welding

Whether it be for bridges and other structures, for storage tanks, gas-holders, or for Class 1 pressure vessels and boiler drums, welded construction has "come to stay," on account of its economy of material, tightness of joints, and the neat sound job which welding makes.

Appleby Steel Plates have excellent physical properties, are ductile, flat, well-sheared, and will be found highly suitable to all forms of welded construction in which plates are used.

THE UNITED STEEL COMPANIES LTD

APPLEBY-FRODINGHAM STEEL COMPANY · SCUNTHORPE · LINCS

BRANCH OF THE UNITED STEEL COMPANIES LIMITED

TELEPHONE: SCUNTHORPE 3411 (9 LINES) TELEGRAMS: "APPROD" SCUNTHORPE

AF.67

The OK Cadet

one hand operation

- Cuts Plates from $\frac{1}{8}$ inch to $2\frac{1}{4}$ inches thickness—CLEAN cuts.
- Will cut circles from 2 inch diameter upwards.
- Straight cuts of unlimited length.
- Cuts bevels.
- For use with acetylene—propane or coal gas.

Please send for O.K. Leaflet No. FC/C 52.

Another OK Product

WELDING SUPPLIES LIMITED

BEECHINGS WAY
GILLINGHAM, KENT

Phone: Rainham (Kent) 81154 & 81600
Grams: Weldsuply, Gillingham, Kent

MANUFACTURERS OF OK ELECTRODES

TRANSACTIONS OF THE INSTITUTE OF WELDING

Vice-President: A. ROBERT JENKINS, J.P., A.I.Mech.E.

PRESIDENT - HOWARD J. THOMPSON, M.I.Mech.E.

Secretary: G. PARSLOE, M.A.

Honorary Editor: D. S. WATT, B.Sc., M.I.N.A.

VOL. 15 NO. 2 APRIL, 1952 PRICE 7s. 6d.

INSTITUTE NOTES AND NEWS

Visit of Dr. James F. Lincoln.—Dr. James F. Lincoln, the distinguished head of the American welding supply manufacturers, is paying a short visit to England at the beginning of May. On 8 May, Dr. Lincoln will address a meeting which is being arranged by the Institute and the British Welding Research Association and will be the guest of honour at a dinner at the Savoy Hotel.

Dr. Lincoln has for many years past interested himself particularly in problems of management and profit sharing. He will speak on the problems of what he has called, in his latest book on the subject, "incentive management" in relation to welding.

Sir William J. Larke Medal Regulations.—The Council of the Institute has decided that in and after 1952 competition for the Sir William J. Larke Medal shall not be restricted to members of the Institute. All papers read to the Institute during the previous session are considered, as well as papers presented to the Branches and selected by the Branch Committees for submission to the examiners. It is also open to any member to submit a paper which has not been read to the Institute or one of its Branches, provided that it is in accordance with the regulations, which were printed in our last issue and are available from the Secretary.

Offers of Papers.—Members of the Institute who are willing to read papers at meetings of the Institute or of its Branches are invited to send particulars to the Secretary for submission to the Programme and Journal Committee, not later than 15 June next. Where the complete text of the paper is not available, a short synopsis should be sent.

Welding in University Engineering Courses.—On the recommendation of the Technical Colleges Sub-Committee of the Education Committee, the Council has agreed to circulate to University Engineering Departments simplified designs of welded constructions, with appropriate annotation, and also to furnish University libraries with lists of recommended text books on welding design. In reply to questions addressed to them by the Sub-Committee, heads of most of the University Engineering Departments in this country have expressed a wish to receive these designs.

C. W. Hill Prize.—On the recommendation of the examiners the Council of the Institute has awarded the C. W. Hill Prize for 1951 to Mr. W. H. Stubbs, Graduate, of the Tyneside Branch. A second prize has been awarded to Mr. J. M. Wright, Graduate, of the Wolverhampton Branch.

Entries for the competition of 1952 must reach the Secretary of the Institute not later than 31 October next.

FRONT COVER ILLUSTRATION.

B.O.C. Aluminium Brazing raises quality *and* output in the manufacture, or repair, of aluminium products, however delicate their detail work. The filler metal, with a melting point lower than that of the parent metal, penetrates right into the joint, driving out the surplus flux. Edges are not melted back, little finishing off is needed, the joint is practically as strong as the parent metal, and the job can be done by a craftsman, without specialist experience.

THE BRITISH OXYGEN CO. LTD.,
LONDON AND BRANCHES

PRINCIPAL CONTENTS

Notes from the Branches 39
The Annual Luncheon 48
Welding in connection with Various Tunnelling Works 43
Welding in the construction of Hydro-Electric Plant 48
Institute Membership 53
Shipyard changes, with special reference to Steelwork Construction in Oil Tankers 54
Latest Additions to the Library 61
Suggestions for Authors of Technical Papers 62
Abstracts from Recent Welding Literature 64

Published by

THE INSTITUTE OF WELDING, 2, Buckingham Palace Gardens, London, S.W.1.

The TRANSACTIONS of the Institute are issued free to Members. To non-members the price of this issue is 7s. 6d. per copy (by post 8s.).

The Institute of Welding is not responsible for and does not necessarily endorse statements made by Authors of Papers and contributors to the Discussions thereon.

Handbook for Welding Design.—After the Ashorne Hill Conference on the saving of steel and man-power by welding, a joint Committee of the Institute and the British Welding Research Association was set up under the Chairmanship of Dr. J. H. Paterson to prepare a scheme for a Handbook for Welding Design. The Committee has now reported and its proposals have been accepted by the Council of the Institute. They involve the production of a Handbook limited in the first instance to the metal arc welding of mild and low alloy steels and arranged in eight sections, as follows:

(1) Arc welding of mild and low alloy steels.
(2) Choice of materials.
(3) Classification of electrodes.
(4) Types of joints.
(5) Design of joints.
(6) Application of joints.
(7) Factors influencing the cost of welding.
(8) Special applications, which includes sub-sections on machine construction, ships, pressure vessels and chemical plant, storage tanks and gas holders, railway rolling stock, structural work and general engineering.

Each of these sections is being compiled by a special Sub-Committee. The Chairmen of these Sub-Committees have been appointed and are at present engaged in collecting the personnel of their Sub-Committees from experts in their own neighbourhood. It is hoped that the drafts of the various sections will be ready for examination by the main Committee in the early summer.

Ashorne Hill Summer School of Welding.—Mr. E. Seymour-Semper has been appointed to represent the Institute with Mr. F. Koenigsberger on the Organising Committee for the Summer School, which, as announced in our last issue, will be held at Ashorne Hill from 16 to 25 July next.

Notch Bar Testing Symposium.—The papers and discussion, together with the written contributions to the Symposium on Recent Developments in Notch Bar Testing and their Relation to Welded Construction are now being prepared for publication as a book. The price will be announced later.

Handbook for Welded Structural Steelwork.—A new edition of this Handbook will be produced in the course of the next few years. The Structural Welding Sub-Committee, which has charge of the work, would welcome suggestions from readers as to changes, improvements and additions which might be introduced in the new edition. Readers are invited to send such suggestions to the Secretary, The Institute of Welding, 2, Buckingham Palace Gardens, London, S.W.1.

In the meantime, copies of the fourth revised edition are still available, price 10s. per copy, post free. This edition incorporates a number of important corrections to the formulae on pages 111-118 of the fourth edition. Members who have the original fourth edition are invited to apply to the Secretary for copies of the corrected pages, which will be supplied post free.

List of Welding Films.—A list of films on welding and allied processes has been compiled in the library of the Institute and is available to members, price 1s. 6d. (to non-members 2s. 6d.). The list contains the exhibition details and brief synopses of 73 films, which are classified under 13 subject headings. A simple reference system enables one to find the name and address of the suppliers of each film. The list should be very useful to teachers of welding wishing to find appropriate films on any given aspect of the subject.

Reprints.—Reprints of the following papers in *Transactions* are available at the prices named: R. G. Braithwaite and D. J. Davies, "Welding in Bridgework and Allied Structures" (paper, illustrations and discussions reprinted from the December, 1949, and February, 1950, issues, price 2s. 6d.); R. Weck, "An Account of M. Henri M. Schnadt's Ideas on the Strength of Materials and his Testing Methods" (reprinted from the April, 1950, issue, price 2s.).

Binding of Transactions.—Arrangements have been made for the binding of members' volumes of *Transactions* in black embossed leathercloth at a cost of 10s. 6d. each, plus 1s. for postage and packing. Members wishing to take advantage of this arrangement should forward parts, with index, to Mansell (Bookbinders) Ltd., 41, Britannia Row, Essex Road, London, N.1.

Index to Transactions.—The index to Volume 14 (1951) of *Transactions* is published with this issue.

I.I.W. Meeting—Gothenburg.—The 1952 meeting of the International Institute of Welding will be held by invitation of the Swedish Welding Society at Gothenburg and will open on Monday, 8 September. The meeting will be made up of the usual series of discussions by the technical Commissions and there will be one open session, devoted to "Welding in Shipbuilding," on the afternoon of Thursday, 11 September. Mr. H. H. Hagan has contributed a paper to this session by invitation of the President of the International Institute.

Chemical Engineering Congress.—Dechema announces Achema X Chemical Plant and Apparatus Exhibition and Chemical Engineering Congress to be held at Frankfurt-am-Main from 18 to 25 May, 1952. The official invitation has now been issued and copies will be sent to those who apply for them to Dechema, Deutsche Gesellschaft für chemisches Apparatewesen E.V., Frankfurt M.—West 13, Postfach, Germany.

B.W.R.A. 1952 Summer School on Welding.—As previously announced, the B.W.R.A. will hold its second Summer School on Welding at Ashorne Hill, nr. Leamington Spa, Warwickshire, from Wednesday, 16 July, until Friday, 25 July, 1952.

Two main courses will be organised. The first, from Wednesday 16, until Saturday, 19 July, 1952, is intended for welding-shop foremen, charge hands, welding operators and others concerned with purely practical aspects of welding fabrication. It will include a series of lectures and discussions on modern welding practice and the basic elements of welding science. These will be supplemented by extensive demonstrations of welding and cutting processes.

The second course, from Monday 21 until Friday, 25 July, 1952, will comprise four separate groups on the following special aspects of welding—Metallurgy and physics of welding; testing and inspection; design for welding by analysis and experiment, and welding engineering. For each of these groups the programme will consist of lectures and discussions covering a wide range of subjects under the particular group heading. This part of the school has been arranged for those who are concerned with the more technical and scientific branches of welding.

Further details and application forms for membership of the school can be obtained from the Organising Secretary, B.W.R.A. Summer School, 29, Park Crescent, London, W.1.

Associate-Membership Examination.—An examination for Associate-Membership of the Institute will be held on 8, 9 and 10 July next.

BRITISH STANDARDS

The following British Standards have just been issued and are commended to readers: B.S. 499 : 1952 (Section 7)—Scheme of Symbols for Welding, price 6s. B.S. 1821 : 1952—Oxy-acetylene Welding of High Temperature and High Pressure Pipelines, price 6s. B.S. 639 : 1952—Covered Electrodes for the Metal Arc Welding of Mild Steel, price 4s.

NOTES FROM THE BRANCHES

MANCHESTER BRANCH NOTES

The following are brief reports of recent meetings of the Manchester Branch, which readers will agree has had a good year. The first paper of the year was given by Mr. E. J. Mitchell on 31 October and entitled "Can it be Welded?" A report of this paper when it was given to the Liverpool Branch was printed in the *Transactions* for June, 1951.

On 5 December last Mr. E. J. Heeley gave a paper on "The Design of Welds for Pressure Vessels" in which he discussed the various types of welds involved in pressure vessels and the special requirements for each. These welds were required to carry, without failure, the fluctuating stress loadings to which they would be subjected under operating conditions and also to be "liquor-tight" under pressure or vacuum. Welded pressure vessels were often required to contain toxic or corrosive fluids, and in the case of vessels made in corrosion-resistant materials it was often essential that the weld metal should be similar in chemical composition to the parent material.

The various types of welds involved in pressure vessels were considered in four categories: (*a*) butt welds, (*b*) welds attaching jackets to vessels, (*c*) welds attaching flanges to vessels, branches and pipes, and (*d*) welds attaching branches and mountings to vessels.

Discussing the most important factors for ensuring that the welds were of the high standard required for pressure vessels, the lecturer emphasised the importance of providing adequate accessibility for welding, illustrating this point by a number of examples of accessible weld preparations and contrasting them with certain widely published types of welds, which he criticised on the score of poor accessibility.

In the detailed consideration of the four main types of weld, Mr. Heeley dealt with the difficulty of computing the local and general stress imposed on many of the types of welds involved in the attachments to pressure vessels, the main exception being the butt weld, where the dimensions of the weld were fixed by the thickness of the plates being welded together. In butt welds the designer's duty was to provide the form of weld preparation necessary to ensure full accessibility, and thus to facilitate the production by the welding operator of welds of the requisite standard of quality.

Attention was also drawn to the necessity for adequate supervision of welded work on pressure vessels and the importance of ensuring that second side welding grooves prepared by chipping or machining were of the correct shape and depth.

The same consideration regarding the provision of a welding groove of adequate accessibility also applied to the very important circumferential welded seam employed to attach a "jacket" to a vessel and the lecturer gave illustrations of the essential features of this type of weld.

Methods of attaching flanges to vessels, branches and pipes were discussed with special reference to the complex stress system involved.

The internal pressure in the system was usually a less important factor in the stressing of the welds attaching flanges, those produced by bolt tightening being of primary importance. As a consequence of (*a*) the lack of precise knowledge of the load on the flange due to bolt tightening, and (*b*) the difficulty of calculating the stress distribution in the flange type of connexion, it was difficult, if not impossible to define the dimensions of the welds employed on the basis of stress in the weld. Consequently the lecturer had adopted the principle of basing the dimensions of welds on the thinner of the two parts being joined together, believing that it was important to ensure that the weld was not the weakest part of the assembly. He went on to discuss the principles involved in determining the best size and shape of welds and described the severe overload test which had been carried out on a flanged pipe to test the stress-carrying capabilities of the weld system adopted. The experimental work showed conclusively that the weld system recommended by the author was of adequate strength to carry without failure the maximum load which could be carried by the thinner of the two parts being joined together and thus confirmed the soundness of the empirical approach to the design of this type of weld system.

Dealing with the attachment of the various types of branches required for pressure vessels, including those in use in the chemical industry, the lecturer mentioned that as the magnitude of the hoop stress in the welded pressure vessel was limited by design, the welds attaching branches to vessels were not ordinarily subjected to load of the same magnitude as occurred in the welds attaching flanges to vessels, branches to pipes, and consequently the same empirical principle, basing the dimensions of the welds attaching flanges on the thinner of the two parts being joined together, must necessarily be safe for the attachment of branches to vessels. The type of weld system employed by the lecturer was less costly than many widely publicised types of branch attachments and had been justified by extensive practical experience over a wide range of welded pressure vessels.

Basic Electrodes

Mr. H. F. Tremlett read a paper entitled "Basic Electrodes and their Characteristics" at the meeting on 9 January, describing a series of tests carried out by the author with various general purpose electrodes. Mr. Tremlett explained that he had obtained a range of electrodes from various manufacturers, had tabulated these under code letters and had had weld runs made with them on various types of joints in mild steel and medium carbon steel.

These experiments proved that a joint made with a basic electrode was sounder than one made with the ordinary general purpose electrodes and that the basic electrode eliminated cracking in the weld zone. It was very important that electrodes should be stored in the correct temperature in order to avoid hydrogen inclusion, which would cause porosity in the welded joint.

The disadvantages of the basic electrode were, in Mr. Tremlett's opinion, (1) their higher cost; (2) that the finished weld run had not the smooth appearance of a run made with a general purpose electrode; and (3) that operators usually preferred the general purpose electrode, because it was easier to manipulate during the weld run.

Mr. Tremlett explained the importance of low sulphur content but expressed the opinion that electrodes might contain as much as 0·06 per cent. sulphur without disadvantage. A high sulphur content either in the electrode or the plate would produce cracks in the weld. He mentioned that 0·80 per cent. carbon steels had been welded with a basic electrode without any weld cracks.

In the ensuing discussion, Mr. E. Fuchs said that his Company had had the same experience in the use of basic electrodes, namely, that operators preferred the general purpose electrode and that the finished appearance of the welds was not so smooth. They had stored their basic electrodes in an oven at 105 deg. C. to ensure that the weld should be free from porosity. Mr. Fuchs was surprised to hear that a 0·80 per cent. carbon steel had been welded without subsequent cracking.

Mr. Fitch criticised Mr. Tremlett's suggestion that 0·06 per cent. sulphur content might be allowed in electrodes; he thought that it should be well below this figure so as to allow for excess sulphur content in the plate. He confirmed the importance of dry storage of electrodes and of the drying of damp electrodes as to expel the last traces of hydrogen. Any dampness in an electrode would result in weld porosity, particularly in the high tensile steels.

Answering a question by Mr. Mortimer, Mr. Tremlett said that the correct preheating temperature for the 40/50 carbon range of steels was 100-150 deg. C.

Mr. Morgan, proposing a vote of thanks, said he was pleased to note the emphasis placed on the use of basic electrodes by Mr. Tremlett. He thought welders should be encouraged to use them and that the factory management should expect to recover the higher cost by greater efficiency in the actual welding.

The Joining of Light Alloys

Mr. W. V. Binstead lectured on "The Joining of Light Alloys" at the meeting on 6 February, reviewing the technical aspects of each of the eight recognised methods, namely, flame welding

processes, argonarc welding, metallic arc welding, brazing, pressure welding, atomic hydrogen welding, carbon arc welding and joining by the use of adhesives. After describing how aluminium and its alloys were produced from bauxite, Mr. Binstead dealt with the heat treatment of high tensile light alloys, including Duralmin and Alclad, for which he offered recommendations as to the type of furnace and salt bath, stressing the importance of temperature control. Mentioning the difficulties in the fusion welding of Duralmin, the lecturer said that it was not the practice to fusion weld this material because of the subsequent loss of ductility and the cracking in the weld or adjacent to the weld. One difficulty in the fusion welding of light alloys was that no appreciable change of colour occurred during welding, which prevented the operator from judging the heat.

One very important point made by Mr. Binstead was that the welding of the light alloys had in the past been veiled in mystery and doubt, but that when the facts were brought into the open and each process was examined in correct perspective, they proved to be no more difficult to weld than other metals and alloys.

Admitting that the joining of the light alloys by adhesives could not strictly be considered welding, Mr. Binstead said that much would be learned about this process in the next few years. It had already been used for joining aluminium to aluminium and aluminium to wood.

In the discussion, Mr. I. Hogg asked why the Sigma method of welding had not yet been introduced into this country. He thought that it was deplorable that we should be lagging behind in this matter.

Mr. Binstead said that he knew of two sets of Sigma welding equipment in use in this country. The difficulty seemed to be related to the patent rights, which were held in the United States.

Mr. R. Bushell said that seam welding of the light alloys did not present any difficulty in itself, but was complicated by the pick-up of aluminium oxide on the seam welding roller path after quite short runs.

Mr. Binstead agreed and said that so far no method had been found to overcome this difficulty.

Mr. Larn then said that by using discs containing wire wool rotating above the electrode wheels, some success had been achieved in reducing the pick-up. Another efficient technique had been the step-by-step or intermittent drive to the electrode wheels.

THE ANNUAL LUNCHEON

THE Annual Luncheon of the Institute was held at the Café Royal, Regent Street, on Wednesday, 30 January last, when the President, Mr. Howard J. Thompson, M.I.Mech.E., took the Chair at a gathering of about 160 members and guests. The Loyal Toast having been honoured,

The PRESIDENT said: It gives me very great pleasure to welcome you all here this morning, and I should like to offer a special welcome to some of our principal guests. We are honoured by the presence of Mr. A. C. Hartley, who, as you all know, is President of the Institution of Mechanical Engineers. (Applause.) Those of you who were privileged to hear his Presidential Address to that Institution will have been very much impressed by his wonderful achievements and by the description of some of the engineering problems which he has had to tackle.

We are also honoured by the presence of the Rt. Hon. Lord Citrine. (Applause.) We are all conversant with the valuable work which he has done as President of the Electrical Research Association and is still doing for the electrical industry. We are delighted that he is able to be with us.

Mr. Thompson then welcomed other distinguished guests, among whom were Sir Charles Lillicrap, President of the British Welding Research Association, Mr. W. S. Grainger, Mr. W. T. Towler, Mr. J. W. Baillie, and a visitor from Quebec, Mr. James Whyte, Chief Engineer of the Shawinigan Company. The President continued:

We are also honoured by the presence of several Past Presidents of our Institute: Mr. C. S. Milne, Dr. J. H. Paterson, Mr. A. Dyson, Mr. W. W. Watt and Sir William Larke. We appreciate the yeoman service of these Past Presidents in helping to bring our Institute to the position which it occupies to-day and we are delighted to see them here.

I should like to say a few words about the work of our Institute during the past year. We have had some outstanding events. One is the visit of the Anglo-American Productivity Team to America. The team was led, as you know, by Dr. Taylor, ably assisted by our Vice-President, Mr. Robert Jenkins, and several of the members of our Council and other members of the Institute. These gentlemen carried out their investigation and produced a very fine book on their findings. They are now devoting a considerable part of their time to going up and down the country, holding discussions and describing what is being done in America. We owe them a great debt of gratitude for that valuable work. (Applause.)

We have had during the year a symposium on notch bar testing, jointly with the Joint Committee for the Testing of Materials. The arrangements were partly organised by Mr. Ford, whom I am pleased to see here to-day.

Through our membership of the International Institute of Welding, we have a very close association with the welding institutes in all parts of the industrial world, and thus gain special knowledge and experience which we are able to pass on to our members. Mr. Milne, a Past President of the Institute, has been appointed a Vice-President of the International Institute, and Mr. Parsloe, our Secretary, has been elected Secretary-General of the International Institute for a further three years.

We are very proud of the part which our Institute played in organising the International Welding Congress during the past year, when some 500 members attended from most of the industrial countries of Europe and America. We have received from very many of them letters of thanks and congratulation, saying how pleased they were to see the strides which we are making in this country in the welding industry. I must take this opportunity to congratulate our Secretary, Mr. Parsloe, and his staff on the organisation of this Congress. The next International Congress will be held at Goteborg in Sweden in September of this year.

Thanks to the loyalty of our members, we have been able to purchase the lease of our offices for forty years. Those offices are a worthy home for our Institute and I think will serve us very well in the coming period.

We are very pleased to work in close collaboration with the British Welding Research Association. Sir Charles Lillicrap, Dr. Taylor and many of their colleagues are members of our Institute, and we in turn are represented on their Council; we have, therefore, a free interchange of opinion, the results of which we are able to pass on to our members.

Your Council are continually trying to improve our Institute, particularly our publications and our library service. As you will realise, the main purpose of our Institute is the education of everyone connected with and interested in welding, which means not only those concerned with welding processes, but also the mechanical engineers, the electrical engineers, the metallurgists and others. They all combine and co-operate in our various organisations and help us in the successful accomplishment of our work.

Means of assisting the universities in bringing welding into its right place in their design courses are at present under consideration, and we are starting to compile a handbook of welding design, parallel to our excellent *Handbook for Welded Structural Steelwork*.

We are very greatly indebted to those gentlemen and firms who have kindly presented prizes for competition among our members.

The Institute's Annual Luncheon, 1952, at the Café Royal

We wish to extend this idea so as to arouse the greatest possible interest and encourage our members to give us papers on the various subjects in which they are interested.

Our Branches to-day number twenty, and we have one in India. Through these Branches, the knowledge that we gain from the International Institute and from the British Welding Research Association is passed on to our members, who are also afforded a means of contact with one another, so that they can exchange ideas and discuss their problems, apart from normal lectures and meetings.

Our Institute does not propose to rest on its laurels. We must look to the future, encourage new members and try to get the support of all those interested, so that we can help to improve the Institute and make it even more worthy than it is now.

Mr. A. C. HARTLEY, C.B.E., M.I.Mech.E., President of the Institution of Mechanical Engineers: It is a very great pleasure to be here as your guest to-day, and I am sure that it will be the wish of the other guests that I should first of all thank you for your hospitality. In looking round, I see among your members and guests friends that I have made at the Institution of Mechanical Engineers and in the Anglo-Iranian Company, which I have had the honour to serve for so many years, and particularly among the members of the firms who have supplied that Company with the wherewithall to carry on their business. Your Institute is extremely widely founded, and a very effective cross-section of the industry. It is therefore with the greatest pleasure that, on behalf of the guests, I thank you for your hospitality to-day.

My first contact with welding, I think, was in 1910, and it was in the forge welding of tie-bars in a water-tank. These tie-bars were duly welded. It was a rectangular water tank, and was sited on the top of the office of our clients, and tested, but unfortunately one of these forge welds failed and the rectangular water tank collapsed inwards and dowsed the office. It was not a good advertisement for welding!

Years later, in the Anglo-Iranian Oil Company, in our pipe lines in Persia we at first used screwed joints. Then, when welding came along, it was obviously the thing for us to use. Much experimental work was done and means were found to weld pipes up to 10 to 12 in. in diameter; but the urge to use welding was rather ahead of the state of the art at the time. Expensive methods were adopted to make the welding easier; for instance, we went to the expense in those early pipe-lines of expanding the last 3 to 4 in of each pipe. We cut off some bits of pipe and put them in, 6 or 8 in. long, for the two lengths of pipe to be stopped on. That facilitated the welding in those days, because it gave a sort of chill plate to burn through on, but, as I say, it was expensive. Further work was done, and it was not long before that extra expense was avoided, and perfectly satisfactory plain butt welds were produced.

Again welding developed. Solid drawn pipe replaced the old cast or lap-welded type, but the solid-drawn pipe could not be made in the diameters which we wished to use. Welding came to help again. Some of you will have seen the plant in Milwaukee which, at that time, 1930, produced more than 20 miles of pipe a day, resistance welded, of up to 24 in. in diameter. Later, since every extra inch in diameter on a pipe-line means tremendous increased efficiency, we went up to 30 in., and even talked of 36 in. It was welding again that made that possible, the Unionmelt method used in Los Angeles. I thought it crazy that for a pipe-line in the Middle East we had to go to Los Angeles. We almost thought of boring a hole in the earth and dropping it straight down, because the two places were about as far apart as they could be. In Los Angeles they had a plate which was very even in thickness, and could be obtained up to 120 to 140 in. in width, and rolled in one piece. That, when longitudinally welded, produced a pipe 36 in. in diameter, and nowhere else could we get it. We saved our face in this country by saying "Let them put out the big quantities; we will put more work into our steel and sell it for higher prices." That, however, is an illustration of how the Americans got ahead. It was no fault of ours, because we had not that width of plate, and it could not have been done here.

Welding has played a tremendous part, and it must play an even greater part in the future. It is able to play a greater part because of the work done by your Institute and by the British Welding Research Association. It is good to feel that this research is being carried out in close association with your Institute, because it is no use saying "Welding is a wonderful thing; we will imitate a casting, and it will do." Inevitably it will fail. You can do much better if you design it from the beginning as a welded structure.

We are in a difficult economic position. An Institute such as yours, which has, for its members, members of the professional institutions and of industrial firms, can bring people together and so make use of what is found out by the British Welding Research Association and put it into immediate and effective

practice. That is what is urgently needed to-day.

On behalf of all your guests, I thank you. We have enjoyed our visit here; we have enjoyed our meal and we have enjoyed your company. We wish the very best of good fortune to your Institute, which has a tremendous opportunity of bringing research quickly into effective use in industry and, above all, in its education and training work, of helping forward young people and giving them the benefit of the experience of its older members, while at the same time giving them initiative and imagination. I am convinced that in the difficulties that we find ourselves in to-day there are greater opportunities than ever before. (Applause.)

The Rt. Hon. LORD CITRINE, President, British Electrical Industries Research Association: I should first like to associate myself with the sentiments expressed by my good friend Mr. Hartley on the privilege of being here and participating in the hospitality which you have provided.

What I do not know about welding, of course, would fill volumes, and on this occasion, as on many others, I am very conscious of the limitations under which I suffer; but I was brought up in a movement where limitations were never regarded as a disqualification of any kind. In a single morning I have taken part in gatherings of half-a-dozen people who have blithely settled the social and economic and political problems of the country and have issued pontifical declarations as a consequence, which no doubt have puzzled, and occasionally astounded, the people who were really concerned with those subjects.

In my wealth of ignorance I cannot traverse the ground which Mr. Hartley has covered, but I do know a little about the work of your Institute. I also, of course, have occasionally come in contact with welders. I have poked my nose into places like Babcock and Wilcox's and seen certain gentlemen hiding behind a mass of armour and working with a torch and producing rather wonderful results. In my earlier days I have come across the welder in shipbuilding and ship repairing, and I know something, although not very intimately, about the difficulties, which you must have had revealed to you in far greater detail than ever I saw, of establishing welding as an essential process in British industry.

I recall the days when it was first proposed that welding should be applied to shipbuilding, for instance, and how the marine surveyors of those days were horrified that anybody should contemplate anything but solid riveting to make a ship seaworthy. However, by introducing the thin end of the wedge—if I remember rightly, by confining welding for a period to the upper structures of the vessels, and demonstrating its superiority there—you were able eventually to get to the more important parts of the ship, from the point of view of the safety of the vessel, and convince people that welding was a perfectly normal and natural and durable process which could save time and labour, and indeed bring many advantages into the shipbuilding world.

Clearly an Institute of this kind is an imperative step in the progress of your profession. We have all long ago reached the conclusion that if you want to do a thing well the common-sense plan is to talk about it to your neighbour who is interested in the same profession and interchange your knowledge with him. There was a time in British industry when people concealed their achievements carefully from their neighbours, lest they might reveal some process which would place them at a disadvantage in competition; but nowadays it is the rule rather than the exception for people gladly to interchange information one with the other, even though they are in competition.

Through such bodies as this it is possible to engage in co-operative research which is utterly out of the question for many of the firms engaged in the processes of welding. The idea of providing a general pool of information from which your members can draw is enormously beneficial to every one of you, and I hope that you all really use the services of your library and the other facilities which are available to you at your headquarters and in your Branches for that purpose.

From your reports, it is evident that you can congratulate yourselves on steady progress. Each of your five thousand members must be an advocate for your work and must greatly help to develop what you are doing.

I was interested in the statement that you now have an International Institute of Welding. It is the easiest thing in the world to sneer at international co-operation. I have had a long experience in another connexion with the international field. While we are all apt to be very insular when we first go abroad, and to think of the superiority from our own point of view of our methods and habits of life, we sometimes find that the fellow in the other country is doing something at least as well as we are, and sometimes a good deal better.

The body with which I am primarily concerned, the British Electricity Authority, uses a great deal of steel, in the erection of power stations, for instance, and in the repairs which have to take place. I was, however, surprised to discover that it is estimated that on a number of our new stations, where welding will be used in the structural work to a greater extent than anything we have previously achieved, it will save about 600 tons of steel per station. That surprises and encourages me, because, as you know, in these days, with the prospective shortage of steel, it is invaluable to discover means of providing the same durable structures with an economy of steel. I am very proud to think that your profession is contributing towards that end.

I am also glad to find that the members of that Authority are keeping themselves up-to-date in what is happening in other countries. It is our practice in the B.E.A. to send people abroad whenever we feel that the exchange of experience can be of benefit to us as a public body. It is easy to sneer at that and to represent foreign delegations as "joy rides," but my own experience in the international sphere was that we started at ten o'clock in the morning, or even earlier, and heaven only knew when we would finish, because continental people have a habit of working in a smoky atmosphere and sticking at it for very many hours—with a small gap of two or three hours for lunch—far beyond the capacity of the average Britisher. I think that it is to the credit of all of us that we can, even in these difficult times, send our people abroad to make themselves familiar on the spot with the latest practice.

I am sure that your Institute possesses, in its library, the journals of almost every type of welding organisation or activity in any part of the world, but, with great respect, I have found that the printed word is one thing, but seeing something in actual operation is another. You can learn a great deal by the mere fact of seeing for yourself and talking with other people and exchanging ideas with them about your problems, more than you can possibly learn if you confine yourself to written publications.

I was happy, therefore, that the B.E.A. sent one of its people with the delegation which was so ably led by Dr. Taylor, because welding to us is becoming increasingly important. I am told that we shall need to train something like fifty Class A skilled welders in the course of the ensuing year, and naturally as tyros in this field we shall be very glad of any help and encouragement that you can give us in effecting that training and making it efficient.

Let me conclude by saying this. Every one of you must feel that there is every prospect of your industry becoming one of the most important in the country. Admittedly it is an ancillary to other processes, and that must be accepted; but it is about the latest thing that has been discovered for assembling great masses of steel and other metals in the most economic and efficient way. When we talk about "welding people together" we are unconsciously paying a tribute to your Institute. Those of you who may have had your little discouragements, first in the prejudices which we all have against new processes and secondly in the difficulties of building up your Institute, may take encouragement from the thought that you are succeeding, and as an outsider, who is sometimes supposed to see most of the game, I feel that you have solid ground for congratulation in the development of your Institute and your profession.

Mr. A. ROBERT JENKINS, J.P., A.I.Mech.E., Vice President of the Institute: I am absolved by the time from making a long speech, but I have to say "Thank you" to both our speakers to-day for coming here. Both are users of welding and of the products of welding, but I think that in Lord Citrine we have first and foremost one of our main suppliers.

We are very happy that Mr. Hartley has talked to us in the kind way he has, because as one of the junior technical institutions we feel very honoured indeed that the President of one of the senior technical institutions should be interested in us and in what we are doing. It is difficult to define a welding engineer, but, as Mr. Hartley has already indicated, he is a man who has a knowledge of mechanical engineering, of electrical engineering and of metallurgy. In other words, we are somewhat of a mongrel; but none

(*Continued on page* 47)

WELDING IN CONNEXION WITH VARIOUS TUNNELLING WORKS

Paper read to the Institute on 26 March, 1952

By E. R. BIDDER, A.M.Inst.W.

Introduction

This paper is concerned with welding rather than tunnelling, and such references to tunnelling work as have been included are introduced to enable the various points at issue, in regard to welding, to be readily understood. The type of tunnel to which welded construction has been applied is that having a circular section and a cast iron lining, such as is characteristic of the deep level underground railways. Though there is one possible exception to which reference will be made, broadly speaking, there appears to be very little prospect of adopting any form of welded steel lining for straightforward tunnelling work; but when considering junctions between horizontal tunnels, or between vertical shafts and horizontal tunnels, or openings in the sides of shafts or tunnels, the use of some form of welded construction becomes of considerable advantage, and this paper deals with works of this kind. Owing to their unusual nature, certain other features containing welded construction have been included, which, while not strictly tunnelling, are used in conjunction with this kind of work.

Cast Iron Tunnel Linings

The castings normally used for tunnel lining, though carefully controlled for quality, are not a highly finished product; the smaller sizes are machine faced only at the radial joints, for the larger sizes both radial and circumferential joints are machine faced, the bolt holes are cored but not drilled. A typical example of such a tunnel lining is shown in Fig. 1. This is the standard 12 ft. internal diameter running tunnel of the London Underground Railways. It is easily seen that the thinness of the arch effects a great saving in excavation, compared with the requirements for a masonry arch. In addition, a masonry arch would entail the use of some form of centering, which would be a serious obstruction within the limited working space available, whereas the cast iron segments are bolted together and immediately become self-supporting.

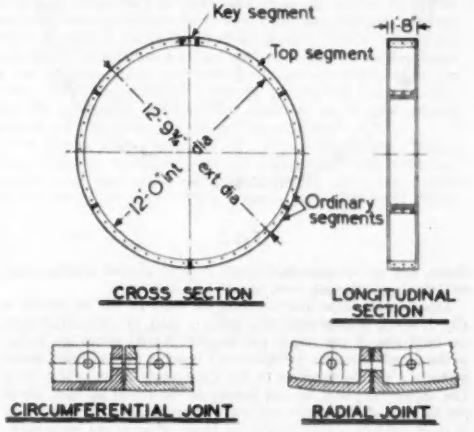


Fig 1

The cast iron ring consists of four lower segments, which are termed "ordinary" segments, having radial flanges at each end; two upper segments termed "top" segments having radial flanges at one end only; and a "key" segment which is inserted last of all. The flanges between the "key" segment and the "top" segments are inclined the opposite way to the keystone of the ordinary arch, to enable the "key" segment to be inserted from inside in an outward direction.

The design is purely empirical, and any figures purporting to show the earth pressures acting on the lining, all indicate that the lining is much over strength.

Reinforcement at Openings in the Side of Tunnels

It must be appreciated that the tunnel lining maintains its shape because it is a complete circle, and that as soon as the circle is broken, as is necessary for the construction of an opening, a support must be provided to resist the circumferential thrust. This may take the form of an arch, a girder, a strut, or a combination of the two latter. For the purpose of calculating the strength of any such support, a uniform pressure of 2 tons per square foot is assumed to be acting radially around the extrados of the lining.

It is in such a situation that a welded steel construction may be employed, with the following advantages: (1) simple design, (2) economy in material, (3) use of shapes which would be almost impossible to fabricate by riveting, and (4) watertightness.

A typical example of a welded steel girder spanning an opening 8 ft. 4 in. wide in a tunnel of 12 ft. internal diameter is shown in Fig. 2. The girder section consists of two rolled angles, each somewhat longer than the actual opening, which are butt welded to a plate forming a shelf to which the cast iron segments are bolted. The plate is the same length as the opening, and fits in between the adjacent complete rings of lining. The portions of the rolled angles which extend behind the adjacent complete rings are butt welded to narrow pieces of plate of the same width as the angle thickness. The whole girder ends are set in concrete abutments. Thus the end reactions of the girder are taken by the concrete, and not by the tunnel lining.

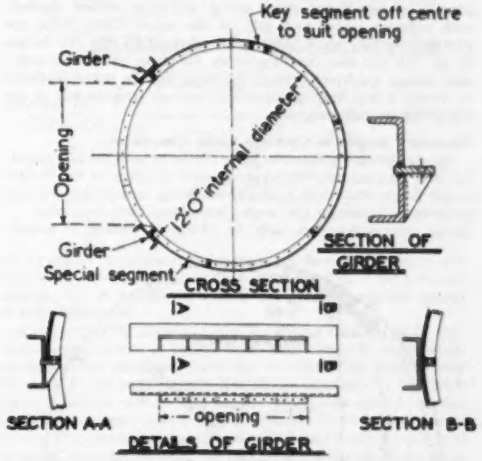


Fig 2

When constructing a similar opening in a larger tunnel, a somewhat different method is employed. A typical example is shown in Fig. 3, which is that of a 7 ft. 6 in. wide opening in a 21 ft. 2½ in. internal diameter station tunnel. This welded girder

was designed in place of a riveted girder of similar overall dimensions, as, owing to the limited depth available, it was impossible to provide adequately for the horizontal shear on the rivets.

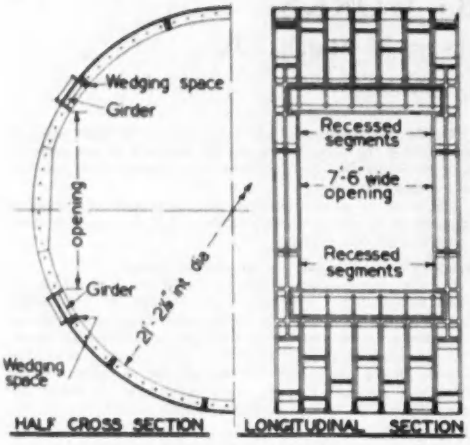


Fig 3

In fact, a riveted girder could not be correctly designed within the required limiting dimensions.

It will be observed that the ends of the girder are recessed into special tunnel segments, which carry the end reactions of the former, and which had been designed already to accommodate the ends of the first intended riveted girder. The welded girder consists of two flange plates and a web-plate welded together, with stiffeners under each joint in the tunnel lining. Since the loading is purely static, fillet welds are used to join the flanges to the web and save bevelling. After the girder has been erected, steel wedges are driven between the flange and the tunnel segments to obtain a firm bearing; these take up any irregularities in the line of the segment flanges.

Temporary Support at Openings during Construction

The two foregoing examples show tunnel openings as completed, but it is essential that temporary support be given to the broken tunnel lining while such openings are being constructed. Various methods of achieving this object have been used, very often of timber construction; but, with the advent of welding, it became possible to design special temporary steel supports for this purpose.

Two devices have been evolved for two different purposes, the "Strut" and the "Tie," examples of which are shown in Figs. 4 and 5 respectively. Each is shown as applied to a 21 ft. 2½ in. internal diameter station tunnel.

The "Strut" shown in Fig. 4 consists of a rolled steel beam with suitable end plates welded on. The thrust from the tunnel lining is transmitted to the strut by means of a number of angle cleats, which are bolted to the tunnel segments, and to a curved steel plate, the latter being welded to a longitudinal rib and a transverse plate. After the strut is in position, steel wedges are driven between it and the transverse plate as necessary. The welds connecting the curved plate to the longitudinal rib are proportional in strength to the total shear strength of the bolts.

It should be added that the example shown is positioned for the construction of an opening in the side of the tunnel, but the strut can be erected in any required position with regard to the tunnel. This is the reason for the use of a number of short angle cleats connecting the curved plates to the tunnel lining, as this facilitates the positioning of the strut, since the cleats will always clear the radial flanges of the tunnel lining wherever they may happen to be.

Although the section of a tunnel may be drawn as a circle, in practice the section may be, and frequently is, slightly out of

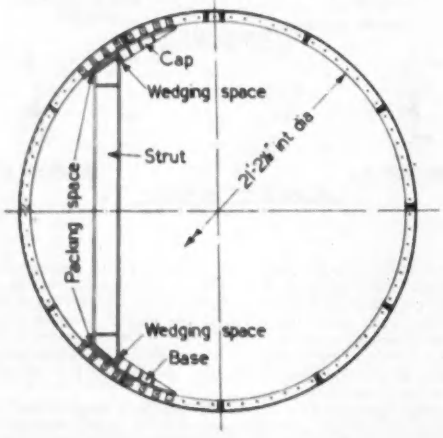


Fig 4

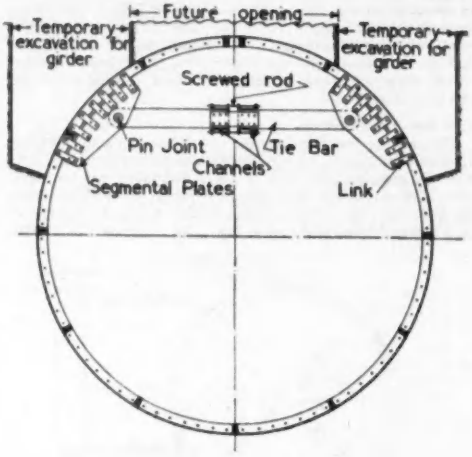


Fig 5

shape, and any construction which is to be applied thereto, must be capable of adapting itself to any such distortion.

This consideration also controls the form of the tie shown in Fig. 5, which is used where the lining is liable to spread outwards. On each side of the tunnel two segmental steel plates are bolted to the tunnel segments by means of a number of steel links, which perform a similar function to the short angle cleats of the strut. The segmental plates are pin jointed to the actual tie bars, which are formed of flat plates and have short lengths of rolled steel channel welded to their upper and lower edges at the inner ends. The flanges of these channels are drilled to receive screwed rods.

To complete the erection of the ties, the two sections of the tie-bar are brought into line, the screwed rods passed through the holes in the flanges of the channels, and the nuts pulled up tight. This has the effect of pulling out any slack that there may be in the bolts of the links connecting the segmental plates to the tunnel segments. This is the sole function of the screwed rods, which are not intended to hold the tunnel in shape, and are incapable of doing so. Once the tie-bars have been pulled in to their correct position, the two sections are connected by means of bolted fishplates, and it is these which prevent tunnel distortion. The bolt holes in the tie-bars are shop drilled, but the fishplates come to the site undrilled, and, after the tie-bars have been pulled into position by means of the screwed rods, the fishplates are drilled to suit, and fitted bolts are inserted.

Reinforcement at Openings in the Crown

For the construction of a large opening in the crown of a station tunnel it was necessary to provide two welded girders as shown in Fig. 6, during the installation of which the tunnel was held in shape by the "tie" shown in Fig. 5. Enough ground had to be

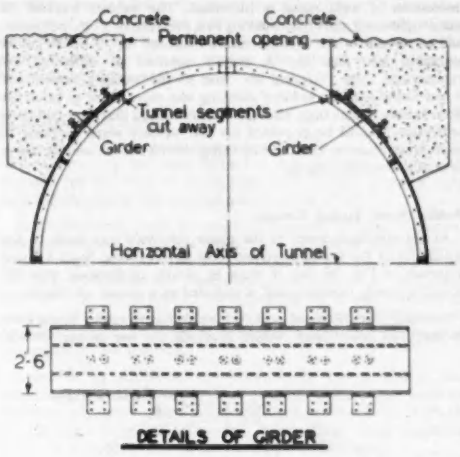


Fig 6

removed to enable these girders to be placed in position. The ground at the time was still in contact with the crown of the tunnel, in the position of the future opening, and thus still exerting its original downward pressure; and since the ground had been removed in the vicinity of the girders, there was a tendency for the lining to spread outwards at these points. Hence before any excavation was commenced, the "ties" were fixed across the tunnel in the position shown, and prevented any movement while the girders were being installed. Once the girders had been installed, and the excavation refilled with concrete, the future opening became self-supporting and the ties were removed.

The girders themselves are of very simple construction, being a channel section, fabricated from two rolled angles butt-welded to a steel plate. Bent plates are used to connect the girder flanges to the skin of the tunnel lining, suitable bolt holes being drilled in the latter. An additional line of bolts is used to connect the web to the tunnel skin, and packings are tack welded to the web to allow for slight irregularities in the tunnel lining. The girder was fixed and cemented in before the circle of the tunnel lining was broken. The cast iron segments were then cut away as necessary to form the permanent opening.

Connexion of Tunnels at Right Angles

An example of a connexion between two tunnels which are at right angles to one another situated in water-bearing ground, is shown in Fig. 7, one being a station tunnel and the other a cross passage. Welded steel plates are used to secure a watertight connexion. The same girders are used as are shown in Fig. 3, but the adjacent tunnel segments are of cast steel, and are site welded to the girders. The connexion to the cross passage is constructed of welded steel plates, and it should be noted that butt welds had to be used at the junctions of the vertical and horizontal plates, as shown in detail "X", to prevent ingress of water along the joint.

Openings connecting vertical shafts to horizontal tunnels have been designed in numerous ways, but the welded steel construction

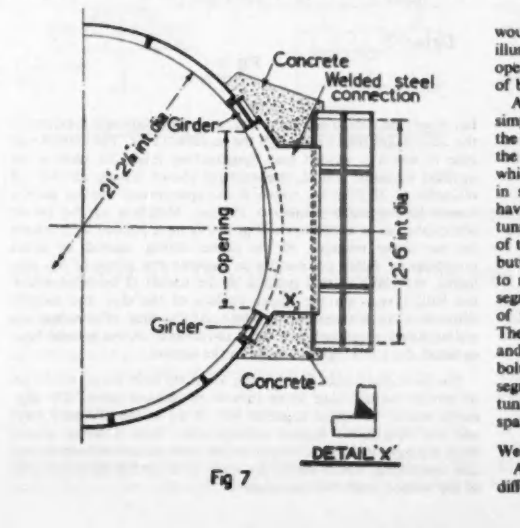


Fig 7

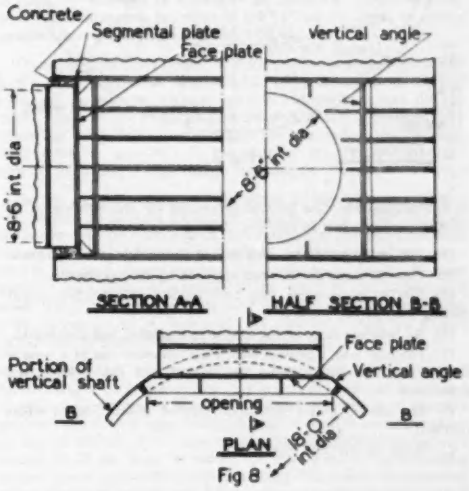


Fig 8

would appear to be the simplest form yet devised. One form, not illustrated, is very similar to that shown in Fig. 2 for a tunnel opening, but in a shaft the girders are of course vertical instead of being horizontal.

Another form is shown in Fig. 8, which, while being of very simple construction, is limited in its application to cases where the face of the horizontal tunnel can be allowed to project inside the circle of the vertical shaft. The design consists of a face plate which is fabricated from four smaller plates, butt-welded together in such a manner that a circular opening is contained therein having the same diameter as the internal diameter of the horizontal tunnel. Connexion between the face plate and the cast iron lining of the vertical shaft is effected by means of two rolled steel angles butt welded to the sides of the former in the appropriate direction to suit the radial flanges of the cast iron segments; and by two segmental plates which are welded to the upper and lower edges of the face plate respectively, together with suitable stiffeners. The whole assembly can be wholly, or partially, shop or site welded, and if desired can be lowered down the shaft in one piece and bolted into position. The space between the upper and lower segmental plates and the extrados of the horizontal cast-iron tunnel, is filled with concrete and grouted, thus forming a concrete spandrel to a cast iron arch.

Welded Curtain Plate

A welded steel construction is also very useful when tunnels of different diameters have to be connected by means of a "curtain-

plate." Such a curtain-plate is shown in Fig. 9, the purpose of which is to obtain a watertight connexion. The example shown was erected in water-bearing ground, the various portions being site-welded

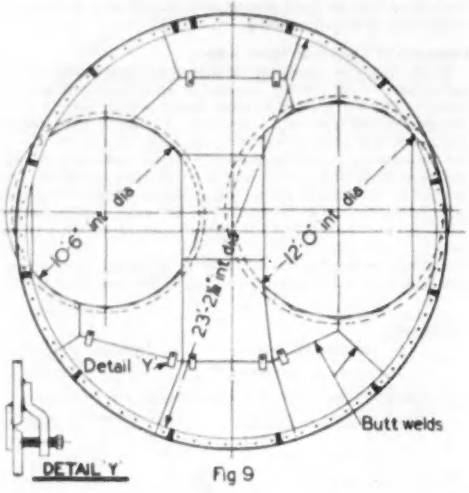


Fig 9

in compressed air. The general procedure for the welding of the various portions was as follows:

(1) The periphery plates were bolted to the cast iron segments.

(2) The adjoining plates were attached by special clamps.

(3) All the plates were then tack welded into position, maintaining a co-planer surface.

(4) All welding clear of the cast iron segments was completed.

(5) The cast iron segments were then removed one at a time to expose the butt-weld behind the flanges and the welding was completed.

(6) The central plates were then erected and cut to fit where necessary.

(7) Welding was then completed.

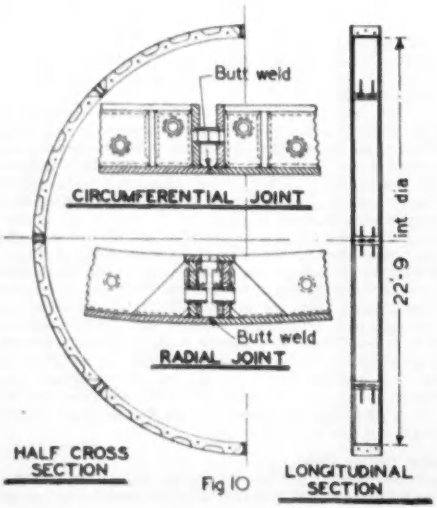


Fig 10

Safety Precautions

The principal points in regard to welding in compressed air are that all welders must be medically examined prior to working; all welding must be done with D.C. owing to the humid conditions prevailing; electrodes are consumed more rapidly and the rate of deposition of weld metal is increased. The welders worked the usual eight-hour shift but, working in a pressure of 35 lb. per sq.in., had to remain in the decompression chamber for 1½ hours before emerging into free air. A certain amount of difficulty was experienced from "fogging up" due to the welding fumes, and it was found that the welders' clothing was more liable to catch fire from sparks. It has been strongly recommended that very complete protection should be provided for the welders when working in such circumstances, but their clothing should not be unduly heavy to avoid excessive fatigue.

Welded Steel Tunnel Linings

At the commencement of the paper reference was made to the possibility of the use of a welded steel tunnel lining. Such a lining is shown in Fig. 10, but it must be clearly understood that the design is purely tentative and is included as a matter of interest.

Normally the increased cost of a welded steel tunnel lining over its cast iron counterpart would preclude the use of the former,

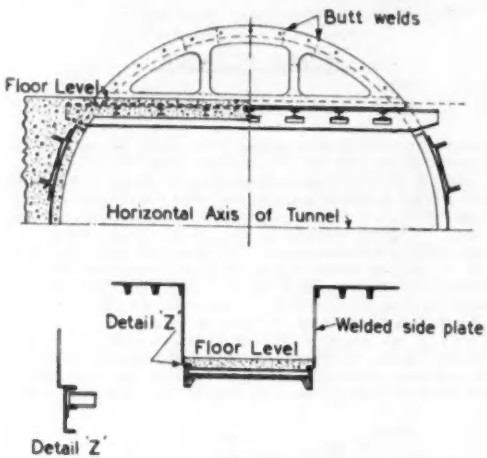


Fig. 11.

but where the tunnel is a short one, and watertightness is essential, the advantages might outweigh the increased cost. The exceptional case in which a welded steel construction might be used is the inclined escalator tunnel, the example shown having an internal diameter of 22 ft. 9 in., which is the appropriate size for such a tunnel having three escalators abreast. Members of the public who make use of escalators will probably have noticed ugly smears on the upper portions of the tunnel lining, caused by small quantities of water percolating in between the joints of the segments, especially in that portion of the tunnel at the level where the ballast rests on the upper surface of the clay and usually contains a certain amount of water. At the time of construction the tunnels are caulked, but small movements of the ground tend to break the caulking, and result in the smears.

The principal object in adopting a welded steel lining would be to provide welded skin joints instead of caulked joints. The segments would be bolted together first of all in the ordinary way, and the skin joints welded subsequently. Such a lining would have a weight of approximately 50 per cent. of the corresponding cast iron lining, which should do much to offset the increased cost of the welded steel over cast iron.

Welded Footbridge

An example of a footbridge in a station tunnel, in which welding has been used extensively, notably in the side plates, is shown in Fig. 11. The side plates must be perforated for purposes of air relief. The lower edge of the side plate is a rolled steel angle, the remaining portion being fabricated from small plates butt welded together. The stringers are rolled steel channels, the ends of the lower flanges being cut and welded to clear the bent plates of the girders and to form an end bearing. The girders below the footbridge are the same as those shown in Fig. 6.

40 ft. All-welded Girder

The 40 ft. span-welded girder shown in Fig. 12 is not actual tunnel work, but has been devised to suit the special conditions required for the roof of an underground station, and has been included because of the unusual nature of the design.

From the traffic point of view it is desirable to bring the upper escalator landing as near to the ground surface as possible. This implies some shallow form of construction, but since a number of short, shallow girders necessitate a multiplicity of supporting columns, the result has to be something of a compromise, as columns in the circulating areas tend to obstruct the flow of pedestrian traffic, and girders somewhat longer and deeper than the minimum are adopted.

There is an additional complication in the particular case illustrated, the station being situated under some public gardens, and it is stipulated that a minimum of 3 ft. of soil be available for the roots of plants above the construction, which condition results in a large increase in the dead load to be carried.

Support to the intervening ground is provided by pressed steel troughing, which to save depth is placed between the girders. With the troughing in such a position, it is not possible to lower it into place, and it has to be inserted between the ends of the girders which are to support it, and to be slid horizontally into position along the length of the girder.

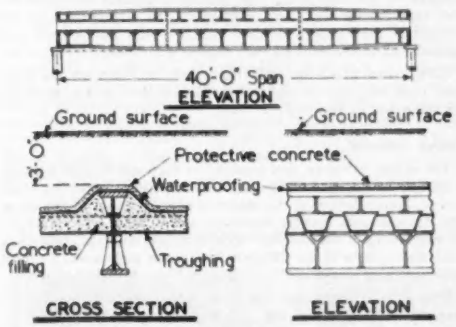


Fig 12

It follows that the vertical stiffeners to the web of the girder must be "interrupted" to allow for the passage of the troughing. Accordingly horizontal stiffeners have been introduced to replace the "interrupted" portions of the vertical stiffeners as far as possible.

It would have been possible to have short pieces of vertical stiffeners bolted or welded to the web after the troughing had been slid into position; but it was deemed desirable to minimise the amount of site work, and let the concrete filling to the troughing provide the necessary local stiffness to the web where there are no stiffeners, vertical or horizontal. The lower horizontal stiffener is placed on the neutral axis of the girder, and also provides the shelf for sliding the troughing into position. Below this horizontal stiffener, local support is provided for the ends of the troughs by means of partial vertical stiffeners having rolled steel angles "on their backs" at their upper ends, connexion being made by butt welds. A flat plate is provided to span the angle and carry the trough across that span, the plate thickness being calculated accordingly. Between adjacent angles a horizontal flat plate is welded to the web, which performs the double function of providing a shelf for the installation of the troughing, and acting as a strut to resist any tendency of the angles to "open out" under the load. Sufficient clearance is provided in the "V" of the angle to turn a spanner through an angle of at least 60 deg.

The vertical stiffeners below the horizontal stiffener are connected to the web by sufficient weld metal to carry the whole of the end loads of the troughs without putting any vertical load on the lower flange of the girder. Where the web thickness changes both upper and lower horizontal stiffeners are interrupted, but sufficient weld metal is provided in the case of the lower stiffener to prevent the adjacent angles from "opening out."

On the general elevation of the girder in Fig. 12, a dotted line will be seen to connect the central portion of the lower flange of the girder with the underside of the column cap; this line represents the plane of the architect's false ceiling. Advantage has been taken of the resulting flange contour to make each flange of three different thicknesses, butt welded in the usual manner. Upper and lower flange contours are made alike, the inclination of the sloping portions being 1 in 24. Butt welds are used to connect the flanges to the web throughout the length of the girder.

The absence of rivet heads is an advantage in both upper and lower flanges, as in the former the waterproofing can be placed directly on the metal of the flange instead of a filling of concrete to cover the rivet heads, and in the latter there is no obstruction to the framework of the false ceiling. This welded girder shows a saving of 25 per cent. in weight of steel over a corresponding riveted girder. All welding is shop welding. The columns supporting the girder are of solid round section, with cap and base slabs welded to the stem.

Acknowledgments

The author wishes to record his indebtedness to Sir David Anderson for permission to present this paper, and to various members of the staff of Messrs. Mott, Hay and Anderson for assistance so readily given.

THE ANNUAL DINNER—*Continued from page* 42

the less we have been and are developing a greater interest in all the engineering products of the day, and we thank Mr. Hartley for coming here and talking to us as he has done, and for indicating to us that interest which we feel it is a great honour to have.

To Lord Citrine I would say that there was a song sung in the First World War called "Keep the home fires burning." (Laughter.) I think that we look to Lord Citrine to keep the home arcs burning, though we admit with some difficulty in the peak hours. I am very delighted to find that Lord Citrine, in spite of his elevated position in the B.E.A., has such a detailed knowledge of the part which welding plays in the structure, boilers, pipe-lines and transformer tanks of his power stations.

I would also pay tribute to Lord Citrine's department, because, although in this I stand to be corrected, I believe that of all the nationalised organisations, the Electricity Authority is the one which has advanced its prices the least. We hope that it will stand by that and not put them up any more! (Laughter.)

In conclusion, I would again thank Mr. Hartley and Lord Citrine for coming here to be with us. We appreciate it very much indeed. (Applause.)

WELDING IN THE CONSTRUCTION OF HYDRO-ELECTRIC PLANT

Paper read at the Institute's Spring Meeting in Glasgow

By J. CRAWFORD, B.Sc.*

AS members of the Institute are to see the factory with which the author is associated during the course of the Spring Meeting, this paper has been framed to further illustrate the character of the work produced therein.

Some three or four years ago the firm entered the field of hydro electric construction, following the conclusion of an agreement with The English Electric Co. Ltd., for whom water turbines and generators are now manufactured at the Scotstoun Works.

The development of inland waterways is being pressed forward throughout the world and ambitious schemes are being put in hand for harnessing very large volumes of water. There is, therefore, a growing demand for very large units, which can fortunately be handled at Scotstoun without embarrassment. The factory has proved to be eminently suitable by virtue of its spacious layout and cranage, its large machine-tool capacity, and in the facilities for expansion and development of a fabrication department equal to the demands of the very largest of hydro-station components.

At the end of the war, welding experience at Scotstoun had been almost wholly confined to relatively small light-weight fabrications, in the main, Admiralty development from original casting design, particularly with reference to the displacement of non-ferrous castings. During the build-up period much experience has been gained and a satisfactory liaison is maintained with the designers which has allowed for continuous development.

There are several forms of water turbine now generally recognised. Many factors influence the selection of type for each specific application.

The impulse or Pelton machine is perhaps the simplest. Deep site excavation is unnecessary, since there is no suction discharge; speed regulation is straightforward, and so the simple character of the unit does not call for fabricated units of any note.

The Frances turbine with reaction type runner may be designed either as a horizontal or as a vertical machine, the variation in component assembly broadly speaking being confined to the water intake and outflow.

The Kaplan turbine with a feathering blade runner has a general layout similar to that of the vertical reaction machine, but with differing control and governing gear.

Reference will, therefore, be made to units employed in typical vertical machines, and while most of the larger static parts of the turbines manufactured at Scotstoun are now fabricated, it is proposed to confine comment to a few of the more important items.

Draft Tube

The draft tube serves to carry spent water to the tail race and has therefore little pressure with which to contend. It serves to turn the vertical fall of the water into horizontal flow in the outlet. Curved pieces of relatively light developed platework are employed as linings embedded in the foundation concrete.

A typical specimen is shown in Fig. 1. This is built of ½-in. thick plate, the transition being from 13 ft. dia. at entry to 24 ft. × 7 ft. at the outlet flange. For ease in building, the draft tube is built up in sections from either end flange by pinning the end flange down on the table and progressively mounting and tacking up each ring of developed plates. When all plates are so mounted the sections are joined and a full-scale check is taken on the building alignment before final welding is commenced. A clean smooth internal contour is essential in the draft tube and welds must be dressed flush and smooth. Any concavity on the suction side (the top inside radius of the curve) is undesirable.

The developed plates for the example shown were burned to profile from templates made to the floor draw-out and then knifed to the required curvature by hydraulic press. As can be appreciated, the assembly of such work will be made infinitely more difficult if individual piece accuracy of each developed plate is not fully attained. It has been found that increased accuracy and considerable time saving have been effected by the employment of the method of development by chart which is now used on all such awkward shaped work with very satisfactory results.

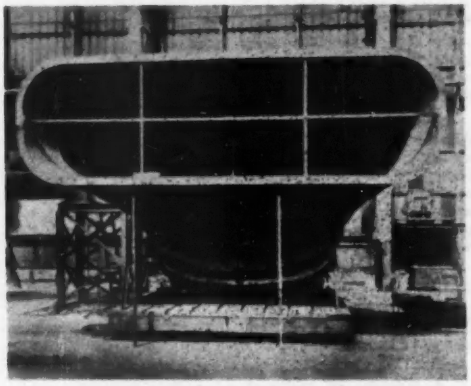


Fig. 1. Draft tube

Such pieces must be built from start to finish on the floor slab, since they are too flimsy for manipulation. Welds, however, are small and quite straightforward.

Runner Envelope

The runner envelope, not required in the reaction type turbine, is used in the Kaplan turbine only and surrounds a feathering blade runner, closely following the spherical swept contour of the blade tips. The clearance between blade tips and envelope is fine and calls for machining of the envelope bore. Stainless steel shell plating is used, and, in view of the vibration from water turbulence, a robust construction is necessary.

Several such envelopes have been constructed. One typical example, as illustated in Fig. 2, has a bore of 14 ft. and is 6 ft. deep. The shell plating is of 1¼ in. thick stainless steel designed to reduce to 1 in. in machining, this putting an extremely fine tolerance on building in view of the 14 ft. dia.

The envelope is constructed as a ribbed framework in three sections vertically, each section in quarter segments with bolted joints. The ribs are 2 in. thick and flanges average 2½ in. To the inside of this framework are welded a series of 72 stainless steel plates (of 18/8 quality) die-pressed to shape. Pressing was done cold in our 2,000 ton press. The profile and weld preparation were planed and chipped after pressing.

The bore shape formed has a concave spherical profile in the mid-region, flaring out at either end of the envelope. The bottom section is made up of a series of double-curved plates.

While distortion proved troublesome in all sections, the lower section was certainly the most difficult, because of the double-curved plates, which prevented correction and introduced a tendency to wind during welding. The fact that the stainless contour plates were welded only to the inside of the cage tended to contract it to a smaller radius, and in an attempt to allow for this we pre-set

* Harland & Wolff Ltd.

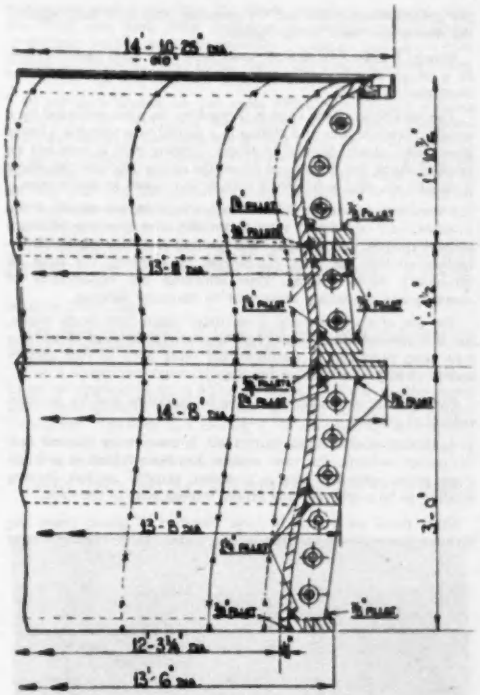


Fig. 2. Sketch of Runner Envelope

the cages large with some success. Finally, however, it was decided to build the rings in eight sections instead of quarters, and thereby afford greater opportunity of balancing form when marking-off for machining the segment ends. Considerable joint face adjustment was needed as an intermediate operation between rough and finish machining of the envelope bore, since there appeared to be a large release of stress on breaking the skin in the bore surface of the stainless plate.

Speed Ring

The speed ring is the entry point of pipe line water to the turbine runner. It further serves as the foundation on which the turbine and generator are erected and therefore it is robust in construction. Both fabricated and cast types have been used, castings being confined to the smaller sets. Fig. 3 is typical of the fabricated types. The ring, 20 ft. dia. and 7 ft. 6 in. in height, weighs 80 tons and is composed of six bolted segments.

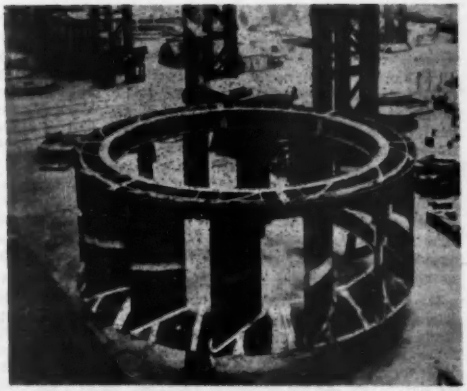


Fig. 3. Speed ring

It is possible to appreciate the construction from Fig. 3, which shows the six segmental sections. Four sections carry two vertical vane plates and the other two have three vanes, making fourteen vanes in the complete ring. These vanes are of 3-in. plate, set to radius by knifing cold in our large press. As can be seen, the vanes extend the full depth of the speed ring and therefore carry directly the total weight of the machine.

The segments are constructed one at a time. The base and top flanged rings with segmental joint flanges are assembled and fairly fully welded on the building block as a first operation. The base ring is then repositioned and the vertical vanes are introduced, pitching and alignment being carefully checked, temporary bracings being used to fit the vanes together. Finally, the partially constructed top ring is then lowered on and aligned. Into the skeleton frame thus far assembled the curved sectional throat plates, which have been hot die-pressed to shape, are set and welding is completed.

The main welds are 1¼ in. fillet welds and at the junction of the fixed vane plate and throat plate a deep V weld is extended to form an external fillet of 1 in.

Fig. 4. Spiral casing being turned over during machining

Spiral Casing

Water is fed to the speed ring by the spiral casing which surrounds it and to which it is welded. An assortment of spiral casings have been completed and are under construction, ranging from the smallest one at 3½ tons weight to the largest shown in Fig. 4. This shows the finish machined spiral and speed ring during shop handling. When it is realised that this piece is 80 tons in weight and 40 ft. diameter the handling problems involved will be appreciated.

The speed ring for this spiral casing is also fabricated and weighs just over 40 tons. Construction of the spiral is carried out round the rough machined speed ring, this rough machining serving as a base for future work and also as the weld preparation for the main spiral-speed ring weld.

Fig. 5 shows the spiral during building. The large inlet end is set up first in correct relationship to the centre line and building is then carried on down to the closing plate of the tail.

The spiral and speed ring is built in quarter segments for final

site welding and therefore joint welds are not fully made, though for service in erection, considerable tacking is done. In its first build-up the spiral is only tacked to the speed ring, so that, on completion of the build up, the quarter segments of the spiral may be taken down for stress-relieving. Substantial bracing is

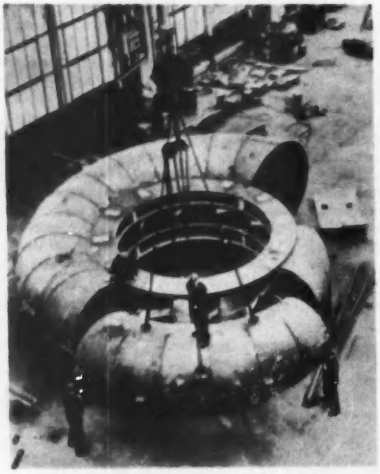


Fig. 5. Assembly of spiral

employed to hold the open throat when this is being carried out. Following stress-relieving the spiral is re-hung on the speed ring and the main weld carried out. There are over 50 curved plates in this spiral, ranging from ¾ in. to 1¼ in. in thickness. The developed size of the largest plate is roughly 15 ft. × 4 ft.

This also is an ideal subject for the use of development by chart. Our first few spiral casings were drawn down in the loft in the usual way and allowance was made for some degree of adjustment during erection. Subsequently we developed by chart and have now so covered the manufacture of over two dozen spiral casings. The resultant accuracy of production of templates reacts on the speed and facility with which erection can proceed.

Guide Vanes

In both Frances and Kaplan turbines a series of guide vanes is mounted inside the speed ring surrounding the runner. These

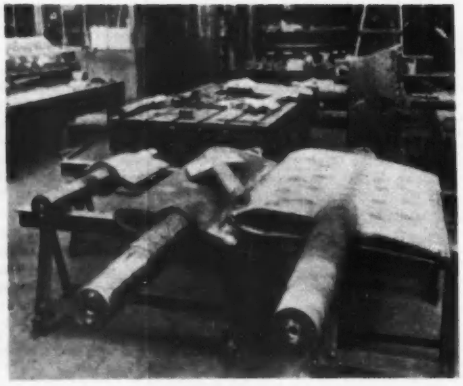


Fig. 6. Selection of fabricated guide vanes

are governor-controlled and, by swinging open and shut, regulate the flow of the water to the runner.

Several hundred fabricated vanes have now been manufactured in a range of sizes with only minor variations from the type illustrated in Fig. 6.

The backbone of the vane is formed by the stem extended by a smaller diameter tube and ending in a turned boss forming a lower pivot. Two plates, pressed to shape, forming with a nose bar an aerofoil shape, are positioned round the centre tube and the whole is welded up, plug welds being used to join plates to centre tube.

Vanes tend to distort to some extent both by movement at the junction weld of stem to vane plates and also by virtue of longitudinal contractions in the welds joining the vane plates. Satisfactory control has been established by spinning the vane on vee-blocks while welding, thus affording the opportunity of checking and correcting movement by balanced welding.

The use of stainless plate is instanced again later in the paper, but it is appropriate to record here that several series of vanes have now been produced in stainless clad plate both in 18/8 quality and in 13 to 14 per cent. chromium.

Facilities are available for cutting by guillotine and for powder-cutting of profiles.

A further development in method is now being carried out. To reduce welding, the vane portion has been folded in a three-stage press operation into a complete aerofoil section, leaving welding to be employed only on the trailing edge of the vane.

Since there are relatively large numbers of guide vanes per turbine, it would appear that batch production of castings might

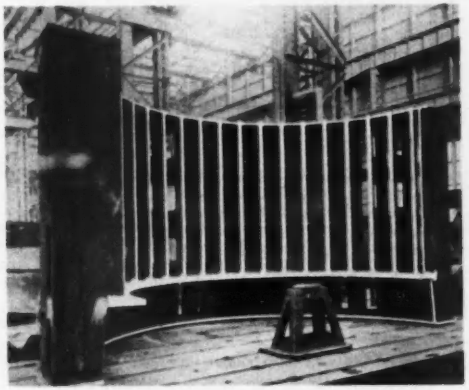


Fig. 7. Half stator frame

be more economical. In view of the good polished finish required on the finished vane, it has been proved that any balance in favour of casting is off-set by the excess time required to bring the rough casting to a finish comparable with that of the plate surface of the fabricated vane. Cast vanes are also suspect because of the tendency to develop draws and faults at the abrupt change of section between stem and vane portion.

Alternator Stator Frame

The stator frame is the only major portion of the typical alternator which is normally fabricated. Fig. 7 illustrates one-half of a typical vertical stator. Two such portions bolted together on the vertical joint complete the stator.

The elements of the piece are top and bottom flanges, horizontal diaphragm plates, wrapper plate and vertical bars, which are finally machined and form the base for the core assembly. The sequence of assembly of each half is first to lay down the base flange for marking out on the building block and thereon to build the vertical ribs and the horizontal diaphragm plates, completing with the top flange. The wrapper plate is then set round. When

adequately tacked together the stator section is removed from the block and, with crane assistance, is manipulated to permit downhand welding as far as possible. To ensure precision in the setting of the bars, which finally carry the core, their positioning is left until the final marking-out for machining.

In our early frames we met some difficulty in limiting welding distortion. The welding of the wrapper to the main horizontal members results in contractional stresses along the outer periphery of the diaphragms and flanges, which tend to open the radius of the half stator. It was found that by arranging for welded joints at 90 deg. from the half-joint faces, any adjustment in the chordal width across the half-joint faces could be readily made, if the quarter-joint weld was held to the last.

The illustrated example has an assembled weight with core plates of 90 tons. The frame itself measures 17 ft. dia. × 9 ft. long.

Straight Flow Valve

This valve is one form of main inlet valve used to control the supply of pipeline water to the turbine.

Fig. 8 shows two representative valve bodies and doors from a range of approximately a score. While so far the smaller types have been castings, there is now a trend toward fabrication throughout. The door as a casting is no easy job for the founder, and we have by now some fair experience of defective castings in the area around the trunnion pins.

The S.F. valve body is roughly spherical in form with a pipeline

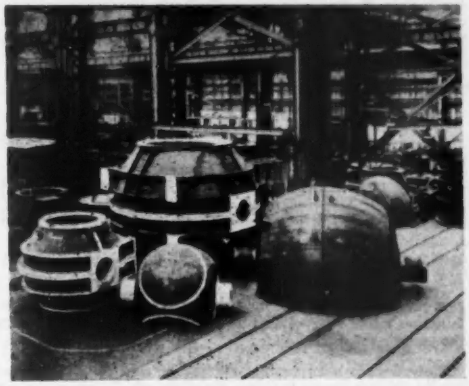


Fig. 8. S.F. valve bodies and doors. Small door is cast

flange at the outer ends of its two portions, which are bolted together on a centre joint. The valve door, a hollow hemispherical piece, is arranged to pivot on heavy trunnion pins in the body bearings. It can be visualised that when the hood-shaped door is in place it will be possible to swing the door over one of the openings to the pipeline and thus close, or alternatively to swing though 90 deg. out of the way of the water stream and open a straight bore for clear water flow.

The door is operated by servo-cylinders taking pipeline pressure and linked to the door by levers bolted to the face of the trunnion pins as they project from the valve body. The valve seatings are of stainless steel, conical in form and are sealed by rubber sealing rings inflated on to the seat by pipeline pressure.

Comment will be confined to the largest valve so far constructed, three of which have been manufactured and tested in the shops.

Fig. 9 shows the door under construction. It has a finished weight of 35 tons, measures 20 ft. across the trunnion pins and seals a pipeline of 11 ft. bore.

As can be seen, the door is of double skin construction with ribs extending right through the double skin, so that all welding can be done externally. The ribs are of 2-in. plate and skin plates are 1¼ in. thick. Welds are U form and of an average size of 1¼ in. The trunnion pins are 30 in. dia. (48 in. dia. at collar), 28 to 35 tons tensile. Austenitic rods were employed for the junction welds of ribs to trunnion pins.

The assembly procedure adopted rested on the initial alignment

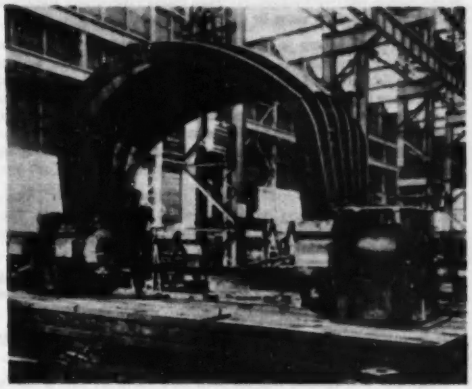


Fig. 9. Door during assembly

and positioning of the trunnion pins in bearing blocks as shown. Assembly of ribs to pins commenced from the centre ribs and proceeded outward in either direction.

Welding was subsequently carried out in the same sequence. Some difficulty was experienced with cracking due, it is considered, to the box construction, which tended to contain locked-up stresses. Constant preheat and continuous welding with extreme care in weld preparation were necessary. Modification of the designed welds was also made before satisfactory results were obtained. For the internal welding the door was suspended on elevated trunnions to allow of downhand welding. Extensive bracing between trunnions was employed in this setting.

Trammel readings were taken as the job progressed, and finally, after stress-relieving both before and after removal of stays. No appreciable movement was found, the final alignment of the pins being accurate within 1/32 in.

One major distortion took place, however, which, though not critical, was surprisingly large. The over tip measurement across

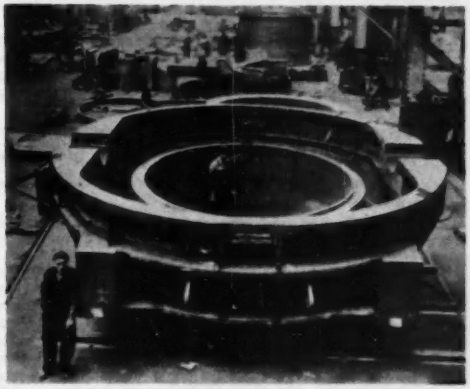


Fig. 10. Half valve body fabricated prior to stress relieving

the hood shrunk by 1½ in. as a result of the cumulative rib weld contractions.

Before leaving the door it should be of interest to consider the machining problem involved.

Trunnions, internal and external conical seating faces have to be machined. The trunnions are machined on a heavy horitontal borer; this is relatively straightforward though obviously alignment setting at 20 ft. pitch must be carefully done.

An elaborate set-up is required on a vertical boring machine for ensuring concentricity of internal and external seats. Service bearings, such as were used for welding, are mounted through the table centre lines, and the door is supported in the overslung and underslung positions for the machining of the conical seatings. These seatings are made up of a mild steel flat, welded into position and machined to take a stainless steel facing, which is built up from small plates welded on to form a continuous face.

Fig. 10 shows an internal view of one half valve body. Again heavy sections and heavy welds tended to lock up stresses. Preheating and continuous welding were used in an attempt to obtain the best welding conditions.

There are minor differences only in the half bodies, amounting to a difference in weight of 5 tons, from 37 tons of the upstream half to 42 tons of the downstream half.

It is interesting to note that the valves assembled for water test have a dead weight of approximately 220 tons when filled.

Assembly was carried out on each half valve by laying down the pipe line and main joint flanges separately on the assembly block and building thereon the cone plates and ribbing, finally marrying the cones together to form the full half body.

The main trunnion blocks were from rolled billets flame cut to shape and planed to size at 17 in. × 21 in. × 60 in. The main joint flanges are 3½ in. plate. The junction welds were with 3 in. V preparation. Serious preheating was required here.

The presentation angles of cone plates to horizontal ribs made certain of the weld preparations rather close and narrow.

Critical points, such as junction welds of blocks to main flange, were selected during welding for gamma-ray inspection.

Stress-relieving of each piece was carried out, and no movement of the fabrication was recorded from marking off before and after stress-relieving.

Use of Corrosion-Resisting Materials

It is obvious that in hydro-electric work corrosion of submerged steel work has to be taken into account and that in certain applications it would be wholly unacceptable.

For example, valve seats over which water speeds are high must remain sound, as pitting would quickly invite cavitation. Deposited seatings of stainless steel or of bronze are usually employed.

Again, there are many applications of rubber piston or sealing rings travelling over cylinder bores or sleeves. Breakdown of the rubber rings would be rapid if the surfaces on which they slide were corroded, and so stainless steel surfaces are utilised in several ways:

(*a*) Solid stainless steel castings.

(*b*) Stainless steel plate provided with flanges, etc., of mild steel.

(*c*) Mild steel cylinder casting with pressed-in liner of stainless steel.

(*d*) Fabricated mild steel cylinder with a stainless steel plate lining wrapped in and plug welded.

Fig. 11 (A) illustrates one of several constructed some considerable time ago. As can be seen, a mild steel drum fabricated and machined in the bore, was lined internally with an unmachined stainless plate ¼ in. thick, set in half plates with a longitudinal seam weld and secured by plug welding. Welding was started in the middle of each plate and continued outwards to the half joint ends. Care was taken to see that the lining was constantly jacked back solid with the mild steel. Approximately two No. 6 rods were used per hole and care in deslagging was essential in view of the slag-trapping tendency of the holes. Following the completion of welding the bore was machined.

(*e*) Fabrications employing clad steels.

Fig. 11 (B) shows a refinement on the method of providing a stainless surface as described and shown in Fig. 11 (A). In this

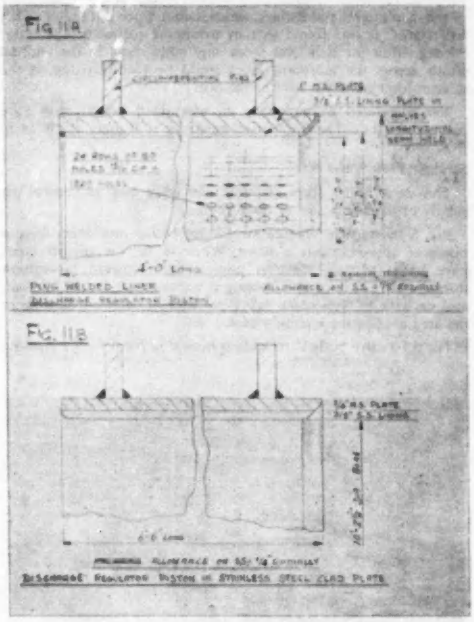


Fig. 11

case pre-machining of the mild steel cylinder and then the later laborious job of plug welding have been rendered unnecessary by the use of stainless clad plate.

Early designs incorporating the use of clad plate have been proved by experience to leave little enough tolerance on the

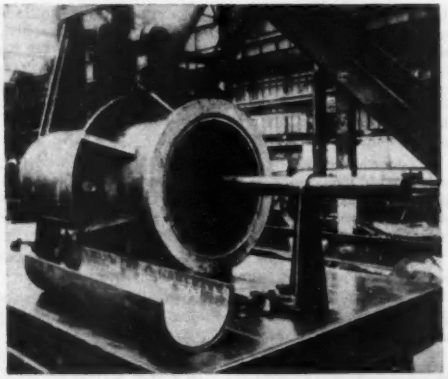


Fig. 12. Servo-cylinder in "Colclad" with set half-plate alongside

accuracy with which pieces could be fabricated and for future production an increase in the S.S. lining is being arranged.

Fig. 12 illustrates the construction of one of a series of cylinders and sleeves produced to date, ranging from 2 ft. 6 in. dia. × 7 ft. 7 in. long to 15 in. dia. × 5 ft. long. The plate thickness is 1½ in. total, made up of ¾ in. mild steel with ¼ in. stainless lining. The intention is to fabricate with a machining allowance of only ¼ in. in the internal radius. Several methods of construction were used successively before satisfactory results were obtained. The final method adopted consisted of cutting clad plates to half cylinder length and half circumference. The assembled short length cylinders were machined to spigot into each other and welded to the full length before final machining. This method minimised the tolerance required to cover the bell-mouthing tendency inherent in the tougher stainless steel component of the plate.

Space does not permit reference to the many other major pieces of water turbine machinery which have by now an established pattern. The trend has been steadily to replace original cast designs with suitable fabrications. Throughout the period of manufacture of the pieces described there has been ample opportunity to make comparison with cast equivalents in both steel and iron.

It has been our experience that steel castings of the shapes required and having so many abrupt changes of section are often unreliable and extensive rectification by welding may be required. Time is lost through the possible late discovery of faults (most of our major castings are pressure castings), and the possibility that further stress-relieving may be necessary risks the accuracy of earlier finish machining. In the case of cast iron, a defective casting more often than not means a complete replacement.

With a fabricated unit, however, the material supply position has, until the present steel crisis, been easier and delivery of the finished piece is within the fabricator's control. There is no doubt also that, piece for piece, fabrication is less expensive when dealing with the large single units that are customary. Weight saving is considerable, probably from 15 per cent. to 20 per cent.

Early reference was made to the necessity for generous handling facilities to deal with bulk and weight in manufacture and a brief reference to shop capacity should demonstrate how adequately this factor is covered.

The fabrication shop comprises two bays 540 ft. long × 90 ft. wide. One bay is served by two 125 ton cranes with a 60 ft. lift and the other bay by two 60 ton cranes with 50 ft. lift, in addition to secondary lighter cranage in both bays. As an example of shop handling, the 120 tons straight flow valve, to which earlier reference was made, has to be assembled on end, then turned on to its feet using the 125 ton crane and moved by bogies on a centre rail track to the erection bay, where it must be moved into position on the test berth with the aid of a lifting beam slung between two cranes.

It is not intended to conclude, as is often done, with a summing up of approved and tried techniques. Obviously it is not possible to carry on the production of such a fabrication department without due regard for the fundamentals of good practice.

Precision at all stages of manufacture is taken as the prime requirement and it is ensured that inspection and checking are adequate to procure this.

INSTITUTE MEMBERSHIP

The following elections were made by Council on 27 February, 1952:—

Members.—E. Christie, Stowmarket, Suffolk; F. G. Clarke, Stoke Bishop, Bristol; C. C. Frayn, Barrow-in-Furness, Lancs; N. Gross, Ph.D. (transfer from Associate-Member), Abington, Cambridge; H. Roscoe (transfer from Associate-Member), Palmers Green, London; C. B. Snodgrass, B.Sc., A.R.S.M., A.I.M., Wombourn, Staffs; R. Weck, Ph.D., Abington, Cambridge; T. Wheeldon, Commander, R.N., Plymouth, Devon.

Associate-Members.—J. S. Allen, West Bromwich, Staffs; T. Barron, A.M.I. Struct.E., Middlesbrough; W. Clarke, Ipswich, Suffolk; J. E. I. Deighan, Glasgow, C.4; D. Ewan, G.I.E.E., Lower Cornal, Dudley; R. W. Humpage (transfer from Graduate), Birmingham, 10; N. Leigh, Preston, Lancs; E. M. Lewis, Walton-on-Thames, Surrey; D. C. Love, A.I.Mech.E., Ruabon, Denbighshire; C. J. M. Napier, A.M.I.Struct.E., Johannesburg; H. M. Nelson (transfer from Graduate), Glasgow, C.1; C. K. M. Percival (transfer from Graduate), London, N.W.3; K. J. Pitkin, A.M.I.C.E., A.M.I.Struct.E., Bulawayo, S. Rhodesia; H. H. Reeve, Rugby, Warwickshire; J. Robson, North Jesmond, Newcastle-on-Tyne, 2; J. C. Rome, Commander, R.N., Bath; B. W. G. Savill, A.M.I. Mech.E., Frimley Green, Surrey; J. S. Strachan, Glasgow, E.1; J. W. Stobbs, A.M.I.Struct.E., South Shields, Co. Durham; P. G. Stokeld, A.M.I.Struct.E., Knightsbridge, London, S.W.1; G. C. Wallace, B.Eng., Barry Docks, South Wales; R. W. Watchorn, Rotherham; P. F. Wilks, B.Sc. (transfer from Graduate), Wolverhampton, Staffs.

Companions.—D. E. Baty, High West Jesmond, Newcastle-on-Tyne; S. R. Cauthery, O.B.E., Chalfont St. Peter, Bucks; E. S. Charlton, Luton, Beds; F. S. Crossman, Major, Old Dalby, Leics; W. Darrington, Darlington, Co. Durham; K. W. Hare, Leicester; J. H. G. Hutchings, Wembley, Middx; C. J. Phelps, Gustavsburg, Germany; A. Whittaker, Barnsley, Yorks; J. H. Wood, Tweedmouth, Berwick-on-Tweed.

Graduates.—N. R. French, Darlington, Co. Durham; D. G. Hill, Leeds, 9; P. S. Marsh, Chelmsford, Essex; J. G. A. Smith, G.I.Mech.E., Palmers Green, London.

Associates.—T. L. Bell, Dyserth, North Wales; L. Brinsden, Battersea, London, S.W.11; A. C. Cambridge, Greenford, Middx; R. F. Campton, Foleshill, Coventry; A. J. Collins, Fulham, London, S.W.6; J. H. Davis, Hoddesdon, Herts; C. E. Dew, Sekondi, Gold Coast; M. Edey, Liverpool, 21; R. Elder, Hall Green, Birmingham; D. Garlick, Sheffield, 5; J. Gorman, Blyth, Northumberland; K. O. Ho, Singapore; A. H. Horton, Morden, Surrey; J. Jackson, Orrell, Wigan, Lancs; F. J. Landeryou, Camel's Head, Plymouth; P. Mellor, Darwen, Lancs; J. Milns, Balby, Doncaster; C. P. F. Rimell, Kingsbury, London, N.W.9; E. H. Saul, Tipton, Staffs; K. S. Sehmi, Nairobi, B.E.A.; M. L. Sharma, A.M.I.E.T., Amritsar, India; W. A. Smithies, Rotherham, Yorks; T. Stanley, Preston, Lancs; W. Stenton, Jarrow-on-Tyne, Co. Durham; C. P. Stringer, Newsome, Huddersfield; F. H. Watt, Seaham, Co. Durham; C. H. White, Newcastle-on-Tyne, 6; N. Y. Willacy, Preston, Lancs; R. G. Wilson, Paisley, Scotland.

Students.—V. Austin, Wellingborough, Northants; D. Blackhurst, Sale, Cheshire; K. W. Collins, London, S.W.9.

Industrial Corporate Members, Class 1.—Chesterfield Tube Co. Ltd., Chesterfield; Darwins Ltd., Sheffield; Firth-Vickers Stainless Steels Ltd., Sheffield, 9; The Park Gate Iron & Steel Co. Ltd., Rotherham; Quayle Bros. Ltd., Sheffield, 6; Donald Ross & Partners Ltd., London, N.W.1; Steel, Peech & Tozer Ltd., Rotherham.

Industrial Corporate Members, Class 3.—H. Steele & Son, St. Thomas, Swansea.

Reinstatements.—L. Robinson, Highbury Vale, Nottingham—*Associate Member*; W. White, Airdrie—*Associate Member*.

SHIPYARD CHANGES, WITH SPECIAL REFERENCE TO STEELWORK CONSTRUCTION IN OIL TANKERS

Paper read at the Institute's Spring Meeting in Glasgow

By J. RANNIE,* M.I.E.S., M.I.N.A.

PROGRESS throughout industry has been characterised by both evolution and revolution, and in these respects shipbuilding has been no exception to the rule. Some of the most remarkable changes have been of comparatively recent origin. They include the application of electric arc welding to steelwork, which, in turn, has entailed considerable alteration to cranage facilities at the building berths, development of transport facilities, supply of welding power and important re-arrangement of yard personnel.

Fig. 1 shows the early *Caronia* ready for launching in 1904. This ship was 650 ft. long, 72 ft. broad, 44 ft. deep and 19,687 gross tons. Pole derricks of simple design and barely sufficient for effective coverage are in marked contrast with the impressive cranes in Fig. 2, which is a flash forward of nearly half-a-century and shows the latest *Caronia* ready for launching in 1947. This ship is 712 ft. long, 91 ft. broad, 53 ft. deep and 34,200 gross tons. These figures reveal something of the great changes born out of new methods.

Fig. 1

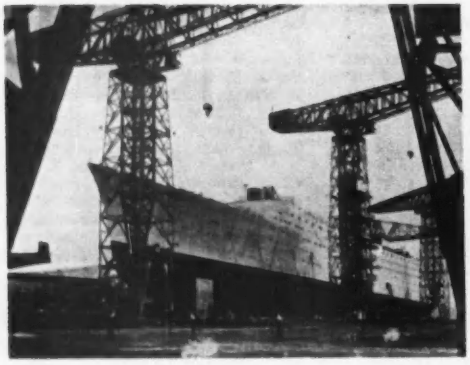


Fig. 2

* John Brown & Co. Ltd.

Berth Cranage

Just prior to the first world war, 45 derricks were erected to service 5 building berths covering approximately 18 acres (Fig. 3). These derricks had an outreach of 65 ft. Several were capable of lifting 5 tons, the remainder 3½ tons. They were semi-portable, mounted on wooden soles and were steadied at the top by 6 or more inter-connected guys. They could be moved bodily to clear ships for launching, or tilted by the head to give clearance at the machinery platform, their broadest part.

That great ships such as *Aquitania*, *Hood*, *Empress of Britain* (shown in Fig. 3), both *Queens* and *Vanguard* were built with these derricks, is a tribute to their effectiveness, and they are still proving their usefulness elsewhere.

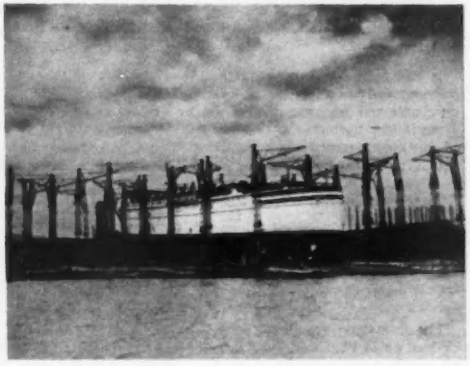


Fig. 3

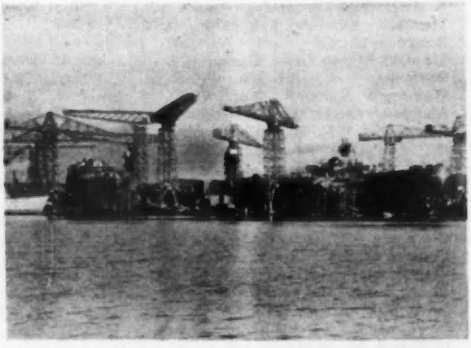


Fig. 4

Fig. 4 shows the yard to-day. The 45 derricks have been replaced by 7 massive tower cranes with a capacity of 20 tons at 140 ft. outreach, whilst at 70 ft. radius 40 tons can be handled. In addition, there are three of a smaller capacity, making a total of 10 cranes serving the same area. A feature of importance in their layout is the fact that their extreme working radii overlap, thus enabling very large panels, too broad for rail transport, to be moved

quickly to the erection point. This overlapping allows a choice of crane, an important point when ships are building simultaneously on adjacent berths.

The foresight shown by the founders of the yard in selecting the site opposite the mouth of the River Cart enables very large ships to be launched, but the berths converge towards the river. This convergence is so great at No. 2 and No. 3 berths, that each

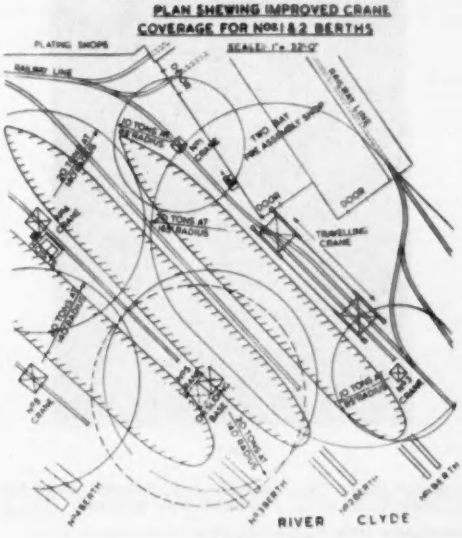


Fig. 5

time a ship is launched, No. 5 tower crane has to be moved up to 25 ft. by means of hydraulic rams and by suspending a 10-ton weight at the maximum outreach to bring the centre of gravity within the portal.

Nos. 1 and 2 berths shown in Fig. 5 were left very poorly off for cranage after removal of the derricks. To overcome this, a travelling crane having a lift of 20 tons at a maximum outreach of 165 ft. and just over-reaching the centre line of No. 2 berth, while at the same time covering the greater part of No. 1 berth, is being erected. By this means large units will be passed direct from the pre-assembly shop door to any other crane in the yard. Incidentally, it will be the biggest travelling crane in a British shipyard.

A complete paper could be written on cranage. Large cranes can be too slow, the hooks too cumbersome for accurate guiding, and their number so reduced that handling of the numerous small lifts remaining after even an exceptional amount of pre-assembling becomes a problem. It is heart-breaking to see a 40-ton crane lift on board a few joinery items. If cranes are high, windage becomes troublesome, the whip of the wires objectionable, and their upkeep costly.

The question therefore might well be asked, "Why then, was the change made?" The answer is found in the ever-increasing use of welding. Welding cannot be carried out satisfactorily and economically without reasonable protection from the elements. The difficulties of erecting welded work are far greater than those encountered in riveted jobs, therefore as many pieces as possible should be joined together, preferably under cover; particularly if true piecework conditions are desired. In other words, the technique of pre-assembling under cover is forced on one by welding; hence the imperative need for large cranes. The cantilever type, several inverted to maintain the height of hook above ground while reducing the actual height of the crane, was chosen in preference to the luffing type as extremely large radii were required while very high vessels were being built.

To relieve the large cranes, several expedients are employed. Two twin electric hoists, each cage capable of lifting 45 men or 3 tons, serve three berths and are extremely useful for transporting sundry material in addition to workmen. To the hoist structure are attached easy-going stairways.

Mobile steam and motor-driven cranes also relieve pressure. The steam cranes, which run on standard gauge tracks, are quite suitable for handling materials up to a distance of 50 ft. from the rails. A small motor-driven crane is lifted on board and does good work erecting lighter pieces and lowering material in holds and pump rooms. Another type is mounted on a caterpillar track and with an extra long jib can lift material from the ground to the deck.

Transport

Internal transport has undergone a great change. Formerly individual plates and sections were man-handled on to bogies and pushed, with or without the aid of narrow gauge rails. To-day there are seven miles of standard gauge rails. Gantries, buildings and rails have in many cases been altered to permit the ready transfer of large units. Tractors, trailers and motor lorries deal with the lighter loads.

Pre-assembly Shop

Whilst improving cranage at the building berths, a concurrent step was to choose the most suitable site for the pre-assembly shop. On the site selected, adjacent to No. 1 berth, had stood for seventy years the shipyard smithy. This was duly pulled down and the pre-assembly shop erected. While the shop proper was in course of construction, a makeshift arrangement was devised, consisting of a shelter mounted on rails and capable of being moved easily by hand. The shop itself consists of two bays of differing heights, one of which was kept on the same low level as the adjacent platers' shed, to allow material to be passed direct into the shop without transfer. It is equipped with two overhead cranes of 15 and 7½ tons capacity and can also be served by an additional crane, if necessary, from the platers' shed. Fig. 6 shows the difference in heights. The higher bay is served by a 20-ton crane and allows panels of 35 ft. sq. to be turned. There are two doors to the pre-assembly shop. The larger and main door facing west has recently been increased to 36 ft. wide and 22 ft. high.

The recent demand for much larger tankers has compelled the construction, in the bay with lesser head-room, of a turning pit 55 ft. long, 6 ft. wide and 10 ft. deep. This enables complete wing bulkheads and transverses, of which there are as many as 90 per ship, to be turned (Fig. 7) and leaves the bay with the 20-ton crane for heavier loads.

Fig. 6

Less spectacular, perhaps, than the changes at the old smithy, but important and inevitable, are those that have occurred in the ancient craft of the blacksmith. Scientific developments, especially in welding and burning, coupled perhaps with a natural bias in man to the less arduous way, have largely displaced the fires and hammers of the past, in favour of welding tongs, burning torches and de-seamers. These new methods have greatly lessened labour and increased output in spite of dwindling man-power.

Welding Power Supplies

About 1930 three substations were erected to supply D.C. power to all the berths. This represents 40 per cent. of the present total

supply, and was then considered sufficient for all future needs. The use of heavier gauge electrodes resulting in the need for A.C. power has necessitated the building, since the last war, of another sub-station between Nos. 3 and 4 berths. This now supplies A.C. power to all berths, and represents 60 per cent. of the supply. The mains are laid in the ground and led to pillar boxes at convenient points between the berths. These contain switch plugs whereby multiple operator transformers are easily connected (transformers remain ashore). From the transformers, cable supplies are led to distribution boxes on the ship.

Cost of Conversion

The following is an approximate statement of the cost of converting a 4-berth yard to allow about 70 per cent. welding and retain about 30 per cent. riveting:

10 Tower cranes, averaging £55,000 each	£550,000
1 Pre-assembly shop	£70,000
3 Cranes for pre-assembly shop—	
1 at 20 tons, 1 at 15 tons, 1 at 7½ tons	£15,000
50 K.V.A. Welding transformers	£10,000
Cables—Permanent mains and welders' leads ..	£8,500
Pillar boxes and spreader boxes	£2,900
2 Unionmelt welding machines	£10,000
300 Regulators	£12,000
300 Welders' masks	£900
300 Welders' tongs	£600
Sub-station buildings, including electrical gear ..	£7,000
First installation labour costs	£1,100
	£688,000

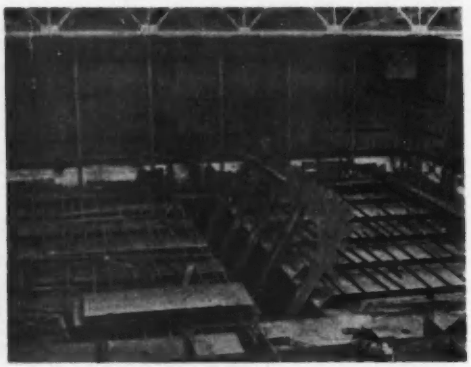


Fig. 7

Quite a staggering total, when one remembers that the total shipyard wages for a large tanker may be no more than £175,000 and the wage bill for welders for one year £125,000. He would indeed be a far-seeing person who could even justify the buying of the cranes; but, on the other hand, without them the ship could not be built. Note the low cost of the electrical parts in comparison with cranes and pre-assembly shop.

Mould Loft Department

The call for bigger ships, combined with restricted floor space, forced the introduction to the mould loft, over thirty years ago, of the marble slab. This slab, measuring 65 ft. × 5 ft., enables the lines for a 1,000 ft. vessel to be faired as accurately and speedily as those of a destroyer of 350 ft. Geometrical methods now displace the mock-ups, and 95 per cent. of the shell plating is developed. The most important advantages are that the ship is maintained "fair," shearing in of shell landings is eliminated, and expensive template wood is saved. It would be true to say that a shipyard with an efficient mould loft, allied with capable fairing squads at the building berths, has one of the main essentials for economic building, and the justification for pre-assembly technique.

While the tankers were still in the design stage, a typical section of structure from keel to upper deck was faithfully reproduced in detail and to a small scale, in light gauge sheet metal. Certain departments, including drawing office and erecting squads, had the opportunity of examining the model, resulting in improvements in design. Manipulation was studied, erecting and fairing methods

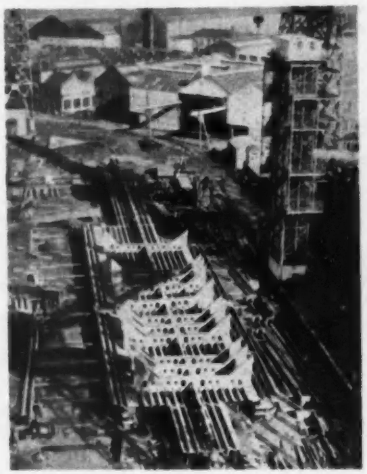


Fig. 8

conceived, and the best positions for semi-permanent staging well considered before the units themselves were produced.

Construction of the Tanker

The main units are erected in the following sequence:

(1) Keel panel consisting of flat and vertical keel, garboards and bottom longitudinals.
(2) Outer panel consisting of B.C. and D. strakes with longitudinals.
(3) Bottom plate transverses in centre tanks.

An assemblage of the above is shown in Fig. 8. An excellent view of one of the hoists already referred to can be seen on the right.

(4) Lower portion of transverse corrugated bulkheads in centre tanks, with lower and middle girders.
(5) Centre line webs, full height.
(6) Wing units consisting of bottom strake of longitudinal bulkhead, transverse floors in wing tanks, lower stringers at shell and bulkhead and "F" strake of side shell.

Fig. 9 illustrates progress to this stage of erection. It is probably unnecessary to emphasise that, from the time of the laying of the

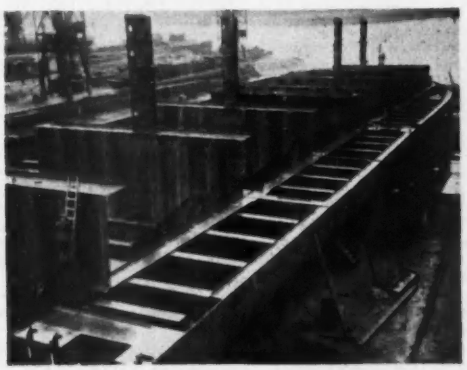


Fig. 9

keel panels, the work of fairing, tacking and welding the various units has steadily proceeded, repeated checks being made to ensure correct local and overall length, breadth and depth. Welding generally is executed from midships towards the free ends, forward

Fig. 10

and aft, port and starboard, and care taken to avoid locked-up stresses.

(7) Transverse corrugated bulkheads in centre tanks, middle girder to upper deck.

(8) Panels of longitudinal bulkheads, from lower stringer to upper deck in depth and a cargo tank in length.

This further development is illustrated by Fig. 10, where the castellation of vertical stiffeners on longitudinal bulkheads is a prominent feature.

This operation of castellation is done by a block punch, and the saving in deadweight capacity is obviously considerable. The pieces removed have holes punched and are welded to units requiring staging; others are positioned at the butts of pre-

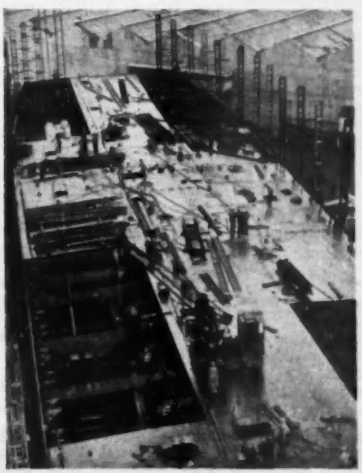


Fig. 11

assembled units to facilitate speedy erection. These staging lugs are not removed but left for the convenience of the ship's staff.

(9) Deck grid, comprising upper deck centre girder and assembled with upper deck transverses, egg-box fashion.

(10) Wing tank bulkheads from lower stringer to upper deck.

(11) Side shell panel consisting of 4 standard size shell plates Unionmelt welded, frames riveted and middle and upper shell stringers welded.

(12) Upper deck centre panel consisting of 3 plates of uniform size Unionmelt welded and with deck longitudinals.

(13) Upper deck outer panels, of similar construction.

In Fig. 11 a view is given of these last items, the midship portion of upper deck being laid. A small motor-driven crane is being used for lighter structural items. The forward and after ends develop naturally on the progress amidships, with superstructure following erection of the upper deck.

The typical oil tanker ready for launching is seen in Fig. 12.

At this stage one or two practical matters connected with construction might be mentioned.

The bogey of contraction has often evoked lengthy discussion, but if an endeavour is made to work to a first time rightness by insistence on accurate loft work without allowance for contraction on the pre-assembled units, and if full use is made of the Unionmelt machines which cause but an infinitesimal amount of contraction, no real trouble should arise.

The advantages of these welding machines are conspicuous on the thicker portions of structure, as deck and shell, especially where appearance is a consideration. The smooth surface, too, of the welded product must eliminate the sea disturbance and its attendant removal of paint, which tends to accompany the coarser hand welding. Several firms have discarded the machines because

Fig. 12

they refuse to weld moist, dirty or poorly fitting joints, but this feature, by demanding an exceptionally high standard of fit-up, in turn contributes to a fair ship, one of the important justifications for pre-assembly.

The increasing use of welding renders an X-ray set a necessity and it is considered that a fixed set, in contrast to a portable one, is adequate for all present requirements in checking the suitability of edge preparation, number of runs, gauge of electrodes, degree of penetration, welding procedure, etc. The ships themselves furnish test pieces of sufficient number and variety, a typical collection is shown in Fig. 13. Proper recording of results and the retention of a judicious selection of small etched specimens, form a most valuable source of reference.

Tank testing also has undergone considerable change. To-day, the first tank only is filled from the water main. This tested, the same water is used for the next tank, being transferred partly by gravitation and partly by pumping through the cargo oil pipe line, already completed and connected to temporary pumps installed in the pump rooms.

Improvements too have been effected in staging, where adjustable uprights on a slide base carry compact steel thwarts for the

wooden stage. Inside the ship costly stage wires are replaced by steel grabs and flat bars not readily susceptible to damage.

So much for the building of the hull of an oil tanker.

The questions now arise "Is the new method better?" and "Is it cheaper?" If for no other reason than the smaller number of

Fig. 13

component parts, it is better, and a study of the operations involved has shown that it is also cheaper. The comparative cost of two different methods is here set out.

RIVETED AND WELDED BULKHEADS
COMPARATIVE COSTS

	Riveted Bulkhead	Welded Bulkhead
Shed Work	£ s. d.	£ s. d.
Loft	3 0 0	3 0 0
Plater	100 0 0	62 10 0
Machinemen	7 0 0	4 0 0
Anglesmith	2 0 0	—
Riveter	57 10 0	—
Welder	—	21 0 0
Caulker	4 0 0	—
Burner	3 0 0	6 0 0
Cranage and stowage	9 10 0	8 10 0
	£186 0 0	£105 0 0
Erection and Completion		
Carpenter	11 10 0	17 10 0
Riveter	21 0 0	—
Welder	—	33 0 0
Caulker	3 10 0	0 10 0
Burner	0 5 0	0 10 0
Driller	0 5 0	—
Stager	8 10 0	8 10 0
Cranage	1 10 0	1 10 0
	£46 10 0	£61 10 0
Total wages	£232 10 0	£166 10 0
Material	£ s. d.	£ s. d.
Steel	845 0 0	669 10 0
Rivets	42 10 0	—
Electrodes	—	29 0 0
	£887 10 0	£698 10 0
Grand Total		
Labour and materials	£1,120 0 0	£865 0 0

The first table deals with a flat bulkhead of riveted construction complete with stiffeners. The second table deals with the corrugated bulkhead welded. For the purpose of comparison, the riveted bulkhead is assumed completed in the plating shop. If it were erected piecemeal at the ship, the carpenters' costs would almost disappear, but those of the plater and riveter would increase.

The cost of the loft work would not vary but the plater would spend a great deal more on the riveted bulkhead, owing to the numerous stiffeners and brackets which are involved. The cost of machining is dearer on the riveted bulkhead due to drilling and the anglesmith appears in the cost of the riveted bulkhead only. The cost of riveting the riveted bulkhead is considerably in excess of the welding cost of the welded bulkhead.

The one trade involved in both methods whose costs are dearer on the welded bulkheads is the carpenter. The erection and fairing of the bulkhead without the aid of rivet holes is responsible for this.

So much for the labour costs, but what about the material costs? Here is the greater saving, if not on a percentage of the whole, then at least in actual amount. Material costs have always been looked upon as the real media for reducing expenditure and in certain instances, where work is awkward, the only means of saving. In the case of these bulkheads it amounts to over £100. A point of interest is that the cost of the rivets is higher than that of the electrodes.

Now examine another part of the ship's structure—the side shell plating. This consists of portions of the plating of two similar-sized oil tankers, the first of which is of conventional riveted construction, having three treble riveted seams and staggered butts, and the second with three Unionmelt welded seams and in panel form. In the case of the riveted shell, the frames, stringers and shell plates are all erected singly at the berth. The various parts for the welded shell assembly are united in the pre-assembly shed, first plates, then frames, followed by side stringers, the whole unit weighing about 18 tons. The vertical butts of the panels are in the centre of the 7 in. flange of the web frames which are erected in advance.

RIVETED AND WELDED SHELL PLATING
COMPARATIVE COSTS

	Riveted Shell (Equivalent Area)	Welded Side Shell Panel
Shed Work	£ s. d.	£ s. d.
Loft	2 15 0	2 15 0
Plater	21 0 0	24 0 0
Machinemen	7 0 0	3 15 0
Welder	—	4 5 0
Riveter	—	22 10 0
Stowage and cranage	1 0 0	1 10 0
	£31 15 0	£58 15 0
Erection and Completion	£ s. d.	£ s. d.
Plater	7 10 0	—
Carpenter	5 0 0	8 15 0
Riveter	47 0 0	10 0 0
Caulker	2 15 0	0 10 0
Welder	5 0 0	7 5 0
Driller	2 10 0	1 10 0
Stager	7 10 0	7 10 0
Cranage	1 0 0	0 15 0
	£78 5 0	£36 5 0
Total wages	£110 0 0	£95 0 0
Material	£ s. d.	£ s. d.
Steel	358 0 0	305 0 0
Rivets	28 0 0	13 10 0
Electrodes, etc.	1 10 0	11 10 0
	£387 10 0	£330 0 0
Grand Total		
Labour and material	£497 10 0	£425 0 0

The plater is again dearer on the riveted job due to the extra work involved in the erection of the plates by him at the berth. The erection and fairing of the completed panel having been carried out by the carpenter, shows his costs greater in the welded

case. The riveting of the riveted shell at the berth, together with the welding of the butts is much more costly than the combined riveting and welding of the welded shell, when most of the work is carried out on the ground.

The riveted shell also calls for more attention by the driller and more caulking. Material costs are again less on the welded shell because of the absence of overlapped seams.

Again, consider a very old but nonetheless efficient method of joining two pieces of steel together, *i.e.* by hydraulic riveting. Compare the costs of the hydraulic riveted bar of a longitudinal bulkhead web and the same bar hand-welded.

COMPARATIVE COSTS OF LONGITUDINAL BULKHEAD WEB FACE BARS

	Riveted	Welded
	£ s. d.	£ s. d.
Plater	17 6	17 6
Machineman	—	1 6
Riveter	13 0	—
Welder	—	10 0
Cranage and stowage	2 0	1 6
	£1 12 6	£1 10 6
Material	£ s. d.	£ s. d.
Steel	1 7 0	1 7 0
Rivets	9 6	—
Electrodes	—	4 6
	£1 16 6	£1 11 6
Grand Total		
Labour and material	£3 9 0	£3 2 0

It will be noted that welding is again the cheaper method.

A comparison of Unionmelt and hand welding costs is shown next. This time a welded deck panel has been considered.

COMPARATIVE COSTS OF WELDED DECK PANEL

	£ s. d.
By Unionmelt Process	
Welder and Labourer	2 17 0
Caulker	9 0
Electrode and melt powder	3 17 0
Electric power	2 2 0
	£9 5 0
By Hand Welding	£ s. d.
Welder	£6 15 0
Caulker	9 0
Electrodes	4 15 0
Electric Power	3 1 0
	£15 0 0

The Unionmelt method with its single pass on each side is very much cheaper than the hand weld with its multiple runs on one side, veeing out and sealing run on the other. The cost of the caulker's work has also been included.

Having now examined four random items with regard to cost, can it be concluded that ships are getting cheaper? Of course they are not; the many increases in wages and payment of holidays have assured that.

But for improved methods, with the resultant increase in output, the cost of building ships would be prohibitive. The following tables indicate what is meant and, in a way, summarise the effects of what has been considered.

Three have been set down for comparison:

IRONWORK LABOUR FORCE

	Year 1914		Year 1928		Year 1951	
	No. of Men	Percentage of Total	No. of Men	Percentage of Total	No. of Men	Percentage of Total
Angle Iron Smiths	26	3·2	15	3·0	2	0·2
Apprentices	9		5		—	
Hammermen	55		36		2	
Platers	322	37·7	150	30·6	258	43·9
Apprentices	83		61		20	
Helpers	458		268		398	
Boys	193		88		4	
Riveters	299	26·4	244	32·3	86	13·3
Apprentices	93		47		2	
Holders-on	166		136		60	
Heaters	182		170		58	
Caulkers and Burners	190	12·5	117	9·9	132	9·1
Apprentices	89		45		6	
Packers	71		20		3	
Drillers	143	8·3	109	9·1	66	4·3
Apprentices	88		60		—	
Welders	—		—		154	12·4
Apprentices	—		—		38	
Shipwrights	139	9·4	160	11·7	163	13·3
Apprentices	65		26		15	
Labourers	58		31		29	
Stagers	71	2·5	62	3·4	54	3·5
	2,800		1,850		1,550	
Output per man per annum	11·9 tons		18·1 tons (52 per cent. increase)		21·6 tons (82 per cent. increase)	
Cost per ton	£7·5		£8·2 (9 per cent. increase)		£20·5 (173 per cent. increase)	
Weekly average wage per man	£1·8		£3 (67 per cent. increase)		£8·5 (372 per cent. increase)	

In 1914 an exceptional amount of templating was done at the ship, holes were punched singly and erection at the berth was carried out by pole derricks. By the second date (1928) multiple and one-man punches had been introduced, electric overhead cranes operated in the shops and electric derricks on the building berths. The third statement relates to the present time, with pre-assembly technique in full swing aided by high speed planes, automatic welding machines, hand welding plant, efficient flame cutting apparatus and X-ray inspection. A general shortage of materials, however, tends to disguise the advantage of the improved facilities now available.

The figures show the considerable numerical changes that have taken place in the ironwork labour force and in the relation between trades. An ominous note is struck by the declining number of apprentices in all trades except welders. Management is now, however, striving to eliminate the casualness of employment, a pernicious disease which drained the industry of many of its best tradesmen and repulsed the intake of youth, but the cure will be slow. For this reason it is often difficult to keep faith both with shipowner and employee.

That output has steadily increased is clear; so alas! has the cost per ton, but not to the same extent as the average weekly wage. One must remember that the 1914 figures are for a 54-hour working week, which by 1928 had been reduced to 47 hours and is now 44 hours. Payment for holidays is also included in the last table. When all facts are considered, the present output per man bears even more favourable comparison with earlier times.

General Data

The following information with regard to the building of a 19,000 tons oil tanker may be of interest.

Whereas formerly 3,500 lifts by derricks were required, now 55 per cent. of the weight is erected as 375 pre-assembled units. These accounted for 42·5 per cent. of the welders' wages. The remaining 45 per cent. of steel weight cost a further 22·5 per cent., work incidental to production another 24 per cent., and finally 11 per cent. was spent on fitting out.

The rivets driven were 32·5 per cent. of those for an all-riveted ship, but at a cost of 37 per cent. Welding displaced the remaining 67·5 per cent. of the rivets and amounted merely to 35 per cent. of the riveting cost of a riveted ship.

Seventeen per cent. of the total ironworkers' wages was spent on welding and 18 per cent. on riveting, while in the all-riveted ship, riveting accounted for 40 per cent. of the ironworkers' wages.

With regard to the welding department, the following is a reasonably accurate statement of what it produced in one year.

Two hundred welders and apprentices used 3,500,000 electrodes (1,000 miles) in 420,000 hours and deposited 2,750,000 ft. of welding (520 miles). By continuous welding this could be deposited in 120,000 hours, 28·5 per cent. of working hours, showing actual burning time = 17 minutes per hour.

The wastage of time is not so tremendous when one considers that 20 per cent. of the electrodes and 35 per cent. of the expenditure were used on minor and scattered work such as

1,250,000 tacks
350,000 bolts, nuts, studs, pins and clips
200,000 lugs and lifting angles
16,000 collars
120,000 hangers
20,000 pipes
100,000 bar butts and ends
6,000 bridges
7,000 pads
12,000 eyeplates or cleats
20,000 handgrips, rail ends and ladder rungs
5,000 stoppers, etc.

13·75	per cent.	of the electrodes	used	were	No. 8	s.w.g.
56·0	,,	,,	,,	,,	No. 6	,,
9·0	,,	,,	,,	,,	¼	in.
0·25	,,	,,	,,	,,	5/16	in.

Despite pre-assembly and all possible downhand work, 20 per cent. of the welding was in the vertical position and 10 per cent. in the overhead position.

In addition two Unionmelt machines used

32,500 lbs. of electrode wire
33,000 lbs. of melt powder

100,000 ft. of welding was deposited in 9,650 welders' working hours.

WELDING EXPENDITURE DURING ONE YEAR

Welders' and apprentices' wages 70·5 per cent. of total	£96,000
Electrodes, 19 per cent. of total	£26,000
672,000 Kilowatt hours of electric power, 10·5 per cent. of total	£14,500
	£136,500

AUTOMATIC WELDING EXPENDITURE

Welders' and helpers' wages, 56 per cent. of total	£4,350
Electrodes and melt powder, 34 per cent. of total	2,650
8,300 Kilowatt hours of electric power, 10 per cent. of total	£800
	£7,800
Grand Total	£144,300

Looking at the colossal amount of electrical energy consumed by the welding plant alone, and remembering that it is only a fraction of the power used in the yard, one ceases to wonder at the imposition of power cuts.

Another reassuring change, mentioned last year by the Chief Inspector of Factories, was that the accident rate in the industry had fallen to an extent which a few years ago had not been thought possible.

The present is a time of abundant research in every field. In engineering, for example, it is being proved that peat and even coal will energise a gas turbine. It has sometimes been thought, however, that shipbuilding and ship design tend to lag behind in the general march of progress. In fact this is not so. Our next tankers will display marked advances on those under discussion and involve at least three major changes.

(1) The framing is longitudinal from keel to gunwale.
(2) The ships will be all-welded.
(3) External staging will be different, as the vessels' increased beam precludes the use of orthodox staging between ships.

This paper has been confined to consideration of some changes related to the construction of steel hulls. Many others related to the equipment and outfitting of these hulls could easily be cited. But while contemplating the development of the last half-century, one naturally wonders what lies ahead during the next fifty or hundred years. Will some new method be devised for joining steel to steel? Will there still be steel? Perhaps the ocean greyhounds of to-day will have become museum pieces, supplanted by space ships. The possibilities in the use of atomic energy are quite unpredictable and before long the presently fantastic may seem eminently reasonable. But this is an enquiry better conducted from the depth of an arm-chair.

Acknowledgment

The author desires to thank his colleagues who have prepared the paper, and the Management of Messrs. John Brown & Co. Ltd., Clydebank, for their permission to use the illustrations and data.

Latest Additions to the Library

As a supplement to the Library catalogue, this section of the *Transactions* contains particulars of books and pamphlets added to the Library during the first quarter of 1952. The books, pamphlets and periodicals specified are available on loan to members of the Institute.

Publications preceded by an asterisk are donations to the Library from authors or publishers; those preceded by a dagger are donated by the James F. Lincoln Arc Welding Foundation.

BOOKS AND PAMPHLETS

***ASSOCIATION OF HEATING, VENTILATING AND DOMESTIC ENGINEERING EMPLOYERS**

Year book of the heating and ventilating industry. Illus. 1951. Publishers: Technitrade Journals Ltd., 8, Southampton Row, London, W.C.1. Price: 7s. 6d., postage 6d.

***BRITISH STANDARDS INSTITUTION**

(a) British standard mechanical tests for metals (excluding welds). Handbook No. 13, 1951. **(b) No. 642—1951.—Calcium carbide (graded sizes). (c) No. 499—7—1952.—Scheme of symbols for welding. (d) No. 885—1952.—Welded steel boilers for hot water central heating and hot water supply. (e) No. 1821—1952.—Oxy-acetylene welding of high temperature and high pressure pipelines.** Publishers: British Standards Institution, 24, Victoria Street, London, S.W.1. Price: (a) 17s. 6d.; (b) 4s.; (c), (d) and (e) 6s.

***BULLETIN OF MECHANICAL ENGINEERING EDUCATION**

Vol. 1, No. 1, Jan. 1952 to date. Publishers: College of Technology, Manchester, 1.

INSTITUTE OF PHYSICS.—INDUSTRIAL RADIOLOGICAL GROUP

Memorandum on gamma-ray sources for radiography. Illus. 1952. Publishers: Institute of Physics, 47, Belgrave Square, London, S.W.1. Price: 3s. 6d.

***LLOYDS' REGISTER OF SHIPPING**

Electric arc welding: electrodes approved for ship construction. Oct. 1951 with addenda to Feb. 1952. Publishers: Lloyd's Register of Shipping, 71, Fenchurch Street, London, E.C.3.

***MACHINERY PUBLISHING CO. LTD.**

Machinery's annual buyers' guide. 24th ed. 1952. Publishers: Machinery Publishing Co. Ltd., Clifton House, 83-117, Euston Road, London, N.W.1. Price: 5s., postage 1s.

STEEL FOUNDERS' SOCIETY OF AMERICA

Recommended practice for the welding of steel castings. Illus. 1951. Publishers: Steel Founders' Society of America, 920, Midland Building, Cleveland, 15, Ohio. Price: 35 cents.

TRADE CATALOGUES

ARO EQUIPMENT CORPORATION

Electrode dressers. (Apparatus for dressing spot welding electrodes.) Address: Bryan, Ohio, U.S.A. Sole Sales Concessionaires: E. P. Barrus Ltd., Brunel Road, Acton, London, W.3.

BLACKWELL'S METALLURGICAL WORKS LTD.

(a) The power behind modern welding is dependent on the electrode used. (b) Powders for coated electrodes. Address: Thermetal House, Garston, Liverpool, 19.

BRITISH FEDERAL WELDER & MACHINE CO. LTD.

Spot, seam, projection, stitch, butt and flash-butt welders. Address: Castle Mill Works, Dudley, Worcs.

BRITISH INDUSTRIAL GASES LTD.

Catalogue of welding and cutting equipment. Address: 32, Victoria, Street, London, S.W.1.

BRITISH INSULATED CALLENDER'S CABLES LTD.

"Bicaloy" for resistance welding. Resistance butt, seam, and spot welding machines. Address: 21, Bloomsbury Street, London, W.C.1.

C. CASPER & CO. LTD.

The new Grampus all square welder's vice. Address: 146-7, Grosvenor Road, London, S.W.1.

CHANCE BROTHERS LTD.

Industrial eye-protecting glasses: Protex arc filters, Protal flux-welding filters for gas welders. Address: Glass Works, Smethwick 40, Birmingham.

CLYDE TUBE FORGINGS LTD.

Welding fittings handbook. Illus. Address: 33, Maiden Lane, London, W.C.2.

COOPER & TURNER LTD.

Arc welding electrodes, plant and accessories. (Full data are given on the electrodes, as well as the British and American classification code numbers.) Address: Vulcan Works, Vulcan Road, Sheffield, 9.

CROMPTON PARKINSON LTD.

Nelson stud welding service. How to lay decks in double-quick time. Fix it like a shot. Address: Crompton House, Aldwych, London, W.C.2.

CYC-ARC LTD.

Stud welders and steel studs, brass studs, stainless steel studs, aluminium studs: designers, patentees and manufacturers of stud welding equipment tools, studs and attachments. Cyc-Arc process in motor-cycle manufacture, in building construction, in stove manufacture, in heat conduction, and acoustic and thermal insulation. Address: Stelmar House, 27-29, New North Road, London, N.1.

GAMMA-RAYS LTD.

Gamma-ray equipment for the non-destructive examination of castings and welding. Address: Foundry Lane, Smethwick, Staffordshire.

QUASI-ARC CO. LTD.

Pipe welding and pipe welding (molybdenum bearing) electrodes. Address: Bilston, Staffordshire.

SMITH WELDING EQUIPMENT CORPORATION

Smith's welding equipment. Address: 2633, Fourth Street, S.E., Minneapolis 14, Minnesota, U.S.A. Sole Sales Concessionaires: E. P. Barrus Ltd., Brunel Road, Acton, London, W.3.

SOLUS-SCHALL LTD.

Ultrasonic flaw detector. Address: 18, New Cavendish Street, London, W.1.

HENRY WIGGIN & CO. LTD.

The Nimonic alloys. Illus. 1952. Address: Wiggin Street, Birmingham, 16.

SUGGESTIONS FOR AUTHORS OF TECHNICAL PAPERS

These suggestions, first published in the "Transactions" in April, 1949, have now been revised and expanded by the Programme and Journal Committee, to give fuller information on the preparation of papers for publication.

I. PAPERS FOR PRESENTATION AT INSTITUTE MEETINGS

WHILE it is hoped that even experienced lecturers may find some of the following suggestions worthy of consideration, the Programme and Journal Committee have set them down with the particular object of helping authors who are preparing for the first time to present a paper to the Institute or one of its branches. The suggestions are offered, not as rules to be observed without question but as hints, based on the experience of other lecturers, and open to such modifications as individual preferences and circumstances may prompt.

The ideal of every lecturer should be a lively presentation of the subject matter of his paper from memory. The notes used should be reduced to an absolute minimum and should take the form of "signposts" which can be seen and recognised by the author at a glance. What the author himself cannot remember, after preparing his paper, will not be remembered by those who hear it read once only, and the attention of the audience wanders when a lecturer has to search among his notes. It is desirable to read in full only extracts of two types, viz.:—

(1) Statements, rules or conclusions which the author has put in a form dependent on the right sequence of words and which must, therefore, be reproduced exactly; (2) quotations from books, previous papers or other published matter.

It is assumed that illustrations are available as lantern slides. These illustrations can be augmented by judicious use of a blackboard, particularly in the discussion following the presentation of a paper.

Four Ways of Presenting a Paper

The author will be faced with one of four tasks, viz.:

(1) Summarising for discussion purposes a paper which practically all members of the audience have read in its printed form beforehand (e.g. most papers at meetings of the Institute).

(2) Presentation at length of a paper which has been available in printed form but which has probably been studied by only a small fraction of the audience (e.g. papers read at branch meetings after publication in the *Transactions*).

(3) "Reading" of a long paper which has not been seen by members of the audience.

(4) Expounding a subject in the form of a descriptive lecture which may or may not be printed at a later date (e.g. most papers given at branch meetings).

In all four cases, the author should first of all explain the aim or object of the paper (e.g. clarifying welding procedure for certain applications, explaining metallurgical aspects of some welding problems, advocating more rigid attention to quality, condemning certain types of jigs as compared with other types, and so forth). It is also of great interest to a listener to hear why the work described was undertaken. Having thus introduced the subject, the author's next step will differ in the four tasks defined earlier.

Summary of Pre-printed Paper (1)

In the first case, summary of a pre-printed paper, the illustrations should now form the framework. The author must be clear in his mind beforehand for exactly which particular point, or points, each illustration is included and, while it is on the screen, he should make only these points, keeping digression to a minimum. Liberal use should be made of the pointer to emphasise the features being stressed, since it is difficult for an audience to pick out these features quickly merely from the verbal description.

Use of the pointer also ensures that the slides are not rushed through too quickly, a fault as great as frequent digressions. When the slides are completed there may remain a number of worthwhile points not yet covered. These should be enumerated as quickly as possible, still assuming that the listeners have read the paper, and finally the author should say how far he considers the object stated in the introduction to have been achieved by the work described and, where applicable, what future line he would advocate and hope to see followed. He will thus have paved the way for full discussion without burdening the meeting with matters already assimilated. A summary as described should not occupy more than 40-50 minutes.

Summary of Pre-printed Paper (2)

Presentation of a pre-printed paper read by only some of the audience, can be treated on the same lines as the first, but the subject may require to be more fully expounded before the illustrations are dealt with, and in showing the lantern slides the author may find it desirable to digress to some extent in order to refer to events or jobs, failures or successes, which stress the importance of the points shown by the photographs or diagrams. The object must be to present the subject matter in such a manner as to impress it on the minds of the listeners in the same way as would a careful study of the paper, but not necessarily by the same words. The author will hold the attention of his listeners if he speaks freely and, as already stated, with the minimum number of notes. A presentation such as this should occupy from 1 to 1½ hours with an absolute maximum of 1½ hours.

Presenting an Unprinted Paper (3)

The "reading" of a paper not previously available to listeners is easier than either the first or the second task, for the subject matter comes fresh to all and the author will clearly have a definite path to tread, since he will have developed his subject in the form of an essay. Reading is again to be avoided except in very small amounts, and a feeling of interest and expectancy must be maintained so that the audience is with the speaker in spirit throughout. This can only be done by a clear exposition, adhering closely to the order and logical evolution used in writing the paper, but again laying stress on highlights and finishing with a summary of the conclusions and recommendations suggested by the paper. The use of a blackboard is often helpful in such a case. The length of a "reading" of such a paper could again occupy from 1 to 1½ hours.

Lecturing (4)

The descriptive lecture as opposed to the paper intended for printing or already printed, can follow the same general rules as the three others. There is no doubt that the lighter touch here is not at all out of place, colloquialisms may well add interest, and an atmosphere of work actually being done or recalled is the right one as an aim for the lecturer. Lecturing, being an art in itself, largely independent of subject matter, be it welding, music, gardening or golf, it is not possible to lay down any hard and fast rules. Again reading should be shunned and there should be an appearance of spontaneous speaking. The time taken will vary greatly, but a maximum of 1½ hours is recommended.

Preparatory Work

Finally, some general words of counsel on the preparation and presentation of papers or lectures. When setting out on the task of preparation, some lecturers have found it well to take the advice of one of very long experience in this field, Bertrand Russell. This advice is to think extremely hard and for some length of time about every aspect of the subject of the paper or lecture a long time before it has to be put into its final form, and then to send the whole matter completely out of the conscious mind, or, in other words, to forget about it quite deliberately. When weeks or months later the time arrives for the final writing of the paper or notes for the lecture, it may well be found that only an absolute minimum of conscious effort is required.

When taking the next step, deciding the words to use when explaining the subject at a meeting, the author should write his "signpost" notes to cover the introduction, the series of illustrations and the conclusion. He should memorise these notes as far as possible, again read his written paper, or full lecture notes, and then await events. Thanks to this thorough preparation, he will, in all likelihood, be able to deliver his paper in words conveying exactly the meaning intended (though possibly quite different from those actually printed or contemplated beforehand). If he does so, his object has been achieved.

Preparation of Lantern Slides

In preparing lantern slides, especially in the case of mathematical expressions and information in the form of tables, great care should be taken to ensure that the illustrations are prepared so

that when projected on the screen they are legible from the most distant part of the room in which the paper is being presented. Many slides of tables and drawings are completely unintelligible because of the very small size of the individual letters and numerals, etc. It is good practice to limit the printed matter to be reproduced on a lantern slide to that which can be included in the original printed or written form within a 5 in. square and at the same time be easily legible at the normal reading distance (of 10 in.). Such matter will be adequately presented on the screen. Where it is necessary to reproduce on a lantern slide the whole of a line drawing or a general arrangement diagram this illustration should be followed by the reproduction on a larger scale of the particular part under immediate discussion.

II. PAPERS FOR PUBLICATION IN "TRANSACTIONS"

If authors of papers for publication in the *Transactions* of the Institute observe the following principles, they will greatly assist the Editor and save time for all concerned.

Consultation with the Editor or his assistant, who are always willing to help or advise, often saves time and effort when an author is in doubt.

(1) The paper itself should be typed on one side only, leaving a margin of about 1 in. on each side and with double spacing to admit of corrections and alterations by the Editor.

Synopsis

(2) The author should send a synopsis of not more than 200 words with the paper. This should be prepared in accordance with the rules in UNESCO'S *Guide* on the subject, copies of which may be obtained from the Editor.

Introductory Matter

(3) The introductory passages should give only such historical information as is strictly necessary for understanding the paper. The point or theme should be reached as quickly as possible.

Sub-Headings

(4) Authors are asked to insert their own sub-headings where they think fit, so as to stress the points they wish to make.

Advertising Matter

(5) Articles must not include any form of advertising matter and reference to firms and proprietary articles and processes should be avoided.

Illustrations

(6) The number of tables and illustrations should be kept to a minimum, as they take up much space and greatly add to the expense of printing the paper. It should be noted that the proper function of illustrations is not to supply the framework of the paper but to illustrate it.

(7) Original drawings and graphs should be submitted, not blueprints, and should be made as compact as possible. The use of the following dimensions, which allow of easy reduction by half for the type page of *Transactions*, is strongly recommended:

14 ins. wide × 19½ ins. (full page)
14 ins. wide × 9¾ ins. (half page)
7 ins. wide × 19½ ins. (half page)
7 ins. wide × 9¾ ins. (quarter page)

Smaller drawings should not be less than 7 ins. wide.

(8) Lettering should be cut to a minimum and shall be at least ⅛ in. in height. It is an advantage to get as much as possible set by the printer, so lettering on the drawing should be kept to the minimum, by incorporating lengthy explanatory matter in the text of the paper.

(9) Sometimes it is necessary to use detailed drawings, but authors should never submit to the editor working drawings, which contain much superfluous detail and are generally unintelligible when reproduced for printing. In such cases the illustrations should be redrawn to comply with the dimensions given in (7) above.

(10) If more than one curve appears on a graph, it is generally better to provide a key than to print alongside the curve. Generally not more than three curves should be drawn on one graph. It should be remembered that the illustration is the curves, not the blank spaces.

It is unnecessary to give the same information in the text as appears on a graph.

(11) It is generally impossible to place the illustrations exactly where the author would like them, but this is immaterial if they are clearly numbered, Fig. 1, Fig. 2, etc., with a brief descriptive caption. Captions and numbers of figures should not be written on the back of the illustration, as the marks often come through and render the block maker's work less satisfactory. They are best typed on a separate sheet and then gummed on the back of the illustration.

Titles

(12) Short titles for papers should almost invariably be adopted. Avoid titles like "Researches into the Structure of Fungi found growing on the lower Slopes of the Alps." Such a title is probably accurate, but for reference purposes (and every author hopes that his work will be of reference value) a more useful title would be "Research on Alpine Fungi," or something to that effect.

References

(13) Footnotes and references cause difficulties to readers and editors and should be used sparingly. Instead of daggers, asterisks, etc., a parenthetical note adjoining the remark is often more intelligible and is much less distracting to the reader.

(14) References should be given by placing the author's names and dates in the body of the text, e.g. "phenomenum of occluded hydrogen (Popoutski, 1938)," and collecting the references in alphabetical order at the end, thus:

Name(s), followed by initial(s) of author(s).

Year of publication in brackets. If several papers by the same authors in one year are cited, a, b, c, etc., are placed after the year of publication.

Journal's title, abbreviated in accordance with the *World List of Scientific Periodicals* (1934, 2nd ed., London: O.U.P.) and underlined to indicate italics.

Volume number in arabic numerals underlined with a wavy line to indicate black type, without prefix "vol."

The number of the first page in arabic numerals, without prefix "p."

Thus references will appear in print in the following form:

Fleming, A. (1929). *Brit. J. exp. Path.*, **10**, 226.
Langmuir, I. (1919a). *J. Amer. Chem. Soc.*, **41**, 868.
Langmuir, I. (1919b). *J. Amer. Chem. Soc.*, **41**, 1543.
Rutherford, E., and Geiger, H. (1908). *Proc. Roy. Soc.* A, **81**, 141.

When reference is made to a book, the title should be underlined; the edition, volume number (vol.) and the pages (p. or pp.) should be given, followed by the town of origin and the publishers, thus:

Romanis, W. H. C., and Mitchiner, R. H. (1948). *The Science and Practice of Surgery*, 8th ed., vol. 1, p. 491. London: Churchill.

References to authors at second hand should appear in the list of references in the following form:

Hering, E. (1915). *v. Graefes Arch. Ophthal.*, **90**, 1. Cited by Hecht, S., in *Physiol. Rev.* (1937), **17**, 239.

All printed sources of information used should be specified.

Proof Correction

(15) The addition of further information to printers' proofs, or their radical alteration, causes delay and greatly increases costs. Authors should, therefore, consider their original typescript as final and should limit corrections in proofs to typographical and other minor errors. Really essential additional information on the subject, received after the article has been submitted, can, however, occasionally be published as an appendix.

Mathematical Formulae

(16) In a publication such as the *Transactions* of the Institute, authors should avoid mathematical formulae as much as possible. If essential, mathematics should be placed in an appendix and kept in the simplest form.

(17) In the use of mathematical, chemical and metallurgical formulae, complex drawings and graphs, and abstruse descriptions and references, all authors should bear in mind the following sound advice from the Royal Society's booklet on *The Preparation of Scientific Papers*:

> "Most journals prefer papers written for the moderate specialist, that is to say, an author should write, not for the half-dozen people in the world specially interested in his line of work, but for the hundred or so who may be interested in some aspect of it, if the paper is well written."

The whole function of science is to make the complex intelligible, and papers that serve that purpose advance the work of the Institute.

Abstracts from Recent Welding Literature

(Compiled by J. L. SANDERS)

THIS section of *Transactions* makes no pretension to completeness but is intended only to provide readers with particulars of some of the more interesting papers appearing in recent welding periodicals.

Readers who need a complete survey should consult the *Bibliographical Bulletin for Welding and Allied Processes* published quarterly by the International Institute of Welding. Particulars may be had from the Secretary of the Institute.

Publications mentioned in the lists below are available on loan to members of the Institute and borrowers will facilitate matters if they will quote the appropriate reference number printed beside each entry.

ARC WELDING.—Submerged Arc

1560. CLAPP, E. A.

Submerged arc welding in tandem

Welding Eng., vol. 37, 1952, Jan., pp. 43-47

This new method uses three phase supply, two electrodes are connected to two of the phases, the ground to the third. The delta three phase circuit has been found to give the best results and welding speeds are claimed to be three times that of the normal submerged arc welding. A table of typical conditions is given.

BRAZING

1561. BEATSON, E. V. and BROOKER, H. R.

Industrial brazing

Welding & Metal Fab., vol. 20, 1952, Jan., pp. 2-11; Feb., pp. 55-61; March, pp. 103-109

Part 1 deals with the suitability of the oxy-acetylene, oxy-hydrogen, oxy-coal gas, compressed air-coal gas and other processes to various materials and classes of work and mention is made of the pre-mixed gas system. The use of fixed torches employing jigs and conveyor belts is discussed and the brazing of a copper alloy cylinder head on a special centrifugal brazing jig is described. Gas and electric furnaces, with and without controlled atmospheres are covered. In Part 2 the authors deal with the following types of protective atmospheres, their preparation and applications: cracked ammonia, cracked and burnt ammonia, partially burnt fuel gas and cracked fuel gas, and compare their costs. Induction heating is described, reference being made to the methods of generating the high frequency current and the construction of the heating coils. Part 3 deals with the resistance brazing, using carbon and interface heating, salt bath and dip brazing processes.

1562. EMMERICH, J. P.

Hints for silver-brazing of stainless steel

Welding J., vol. 31, 1952, Jan., pp. 50-53

After a few hours practice, strong corrosion resistant joints in stainless steel can be made. The author gives a number of practical hints, and tables enable one to select the correct brazing alloy for a given type of stainless.

FLAME HARDENING

1563. GROVER, L. M.

Control of rail-end hardening

Welding J., vol. 31, 1952, Jan., pp. 7-17

The author discusses the flame hardening of carbon steel rail-ends, using both self and compressed air quenching. The proposed recommendations of A.R.E.A. are mentioned and reasons for prohibiting water quenching explained. The equipment may be carried on a truck or towed by a tractor, and details of the necessary equipment are given. The heating flame should be shielded by a suitable box arrangement and heating procedure is described, including details of nozzle dimensions, gas pressures and heating times. The surface hardness ranges from 269 to 341 Brinell. The author then describes the influence of the carbon content of the rail, rail section, gap between rails, initial rail temperature, flame characteristics, heating time and manipulation of torch, and the nature of the air quench on the results obtained. The investigations carried out by A.R.E.A. are outlined, and it is concluded that experience has shown that the methods described yield good results.

GAS WELDING

1564. GALTON, F. T.

The welding of copper pressure vessels by means of the oxygen-acetylene process

Australasian Eng., 1951, Oct. 8, pp. 70-73

The author outlines the precautions and procedures adopted in the welding of copper pressure vessels in wall thicknesses from 1/16 in. to $\frac{1}{2}$ in.

HEAT TREATMENT

1565. JACKSON, C. E. and SHRUBSALL, A. E.

Predetermination of preheat and postheat for submerged-arc welding

Welding J., vol. 31, 1952, Jan. Supp., pp. 1-10

To ensure that the desired properties of alloy steels are obtained in the welded condition, it is essential to understand fully the effects of heat treatment practices. The hardness of a steel depends upon the rate of cooling and the author investigates the effect of weld size on hardness, the relationship between welding technique and nugget area, and nugget area and the maximum hardness in the heat affected zone. The effect of preheat and postheat treatment on ductility is shown and a table gives the postheat times for a range of S.A.E. steels for the complete transformation of the austenite. A set of curves show the time-temperature relationship for their complete isothermal transformation. In conclusion, it is noted that increasing carbon content increases quench hardness, transformation time and the necessary postheat temperature and that postheat treatment should be applied to all steels which are sluggish in their transformation.

METAL SPRAYING

1566. EARLE, F. M.

Metallizing cuts marine maintenance costs

Iron Age, vol. 169, 1952, Jan. 31, pp. 103-105

Fishing vessels completely sprayed with pure zinc or aluminium coating offset the initial expense by lower maintenance costs during the first two years of service. Sprayed zinc is just as satisfactory as a hot dipped surface. The sprayed surface is coated with vinyl sealers to close the surface pores.

1567. SAYRE, H. S.

Development of fused metallized coatings

Welding J., vol. 31, 1952, Jan., pp. 35-39

Metal sprayed coatings are of great value in protecting highly stressed parts operating in sea water. The overlay may be applied by gas welding, arc welding or metal spraying. It is with this last technique that the author deals, in which the sprayed coating is subsequently remelted by the oxy-acetylene torch. The technique of applying a chrome-nickel-boron alloy to steel propellers and propulsion shafts is described.

RESISTANCE WELDING.—Control

1568. LARGE, W. E.

How to get more out of resistance welding control

Steel, vol. 130, 1952, Jan. 28, pp. 68-69

This article describes how the capacity of an existing control system can be increased by the addition of another ignitron contactor with a paralleling or a flip-flop circuit. These circuits are briefly described and curves illustrate the increased capacity.

RESISTANCE WELDING.—Spot and seam

1569. NEWSON, A. J.

Multi-spot welding technique

Sheet Metal Ind., vol. 29, 1952, Feb., pp. 149-157

Describes the application of "Press" welding to the production of the latest Vauxhall cars. "Press" welding is an American term which denotes a system in which the parts to be joined are placed in a fixture or "Press" and the welding heads are lowered simultaneously onto the work. They may be fired together or in a sequence. The machines employed are illustrated and fixture design is dealt with, making particular reference to the electrical problems associated with this equipment.

SURFACING

1570. ANON.
Hard-facing on a production basis
Ind. & Welding, vol. 24, 1951, Sept., pp. 34-37, 75-76
Worn valves are reclaimed by oxy-acetylene depositing cobalt base alloy. Jigs are used to rotate the workpiece which is finally machined, liquid honed and plated to renew the stem life. (M. R.)

1571. POCOCK, P. L.
Hardfacing
J. Iron & Steel Inst., vol. 168, 1951, July, pp. 323-326
The author describes and illustrates the arc and oxy-acetylene methods of hardfacing typical components of the iron and steel industries which suffer from rapid wear. Preheating, depositing, cooling and subsequent grinding are described, with particular reference to the "Stellite" range of hardfacing alloys. (M. R.)

TESTING.—Corrosion

1572. SHIRLEY, H. T. and NICHOLSON, C. G.
Corrosion of welded 18/8 type chromium-nickel steels in concentrated nitric acid
J. Iron & Steel Inst., vol. 170, 1952, Feb., pp. 111-118
An increasing desire to use 18/8 type Cr-Ni steels with high concentrations of nitric acid, often at elevated temperatures, has made it important to ascertain their behaviour under such conditions. Service experience with welded vessels and the use of the Huey test have both indicated the serious selective attack to which titanium-stabilized material may be susceptible, and this paper is mainly a study of the influence of welding on this susceptibility. It is considered that the mechanism is essentially an extension of the well-known intercrystalline corrosion from boundary chromium impoverishment. The conditions are much more severe than those covered by the normal sulphuric-acid/copper sulphate test solution, and in these conditions titanium is a less effective stabilizer than niobium. With duplex titanium-stabilized steels, attack was most severe at delta-gamma boundaries, leading to initial dislodgement of the delta material. Slower attack occurred between austenite grains of sensitized titanium-stabilized material, even without delta-phase, and niobium-stabilized steels could be made susceptible to attack by sufficiently high solution treatment followed by more prolonged sensitization at 650 deg C. It is concluded that 18 per cent. Cr, 8-13 per cent. Ni steels with a 10/1 niobium-carbon ratio should give welds having a satisfactory resistance to this type of attack, even in cases of double welding, such as the sealing welds inside vessels. (Authors' Abstract.)

TESTING.—Gamma rays

1573. TURNBULL, J. G. M.
Radiography of pipe welds with isotopes
Welding & Metal Fab., vol. 20, 1952, Feb., pp. 70-73
The author compares gamma-ray testing with ultrasonic and X-ray methods and states that for site work gamma radiography using Iridium 192 is preferred due to its cheapness and ease of handling, although the results are inferior to X-rays. Gamma radiography should not be expected to detect small basal cracks. Single wall technique should always be used, and on site work it is generally necessary to drill a hole adjacent to the weld for the purpose of source insertion. It is then necessary to fill in this hole with a welded plug. On routine inspection it is possible to train personnel quickly for the operation of the equipment although skilled interpreters are required. The setting up of the source and its container and typical radiographs are shown.

WELDABILITY.—Ferrous.—Alloy Steels

1574. THOMAS, R. D.
Welding of high-alloy castings
Welding J., vol. 31, 1952, Jan. Supp., pp. 27-32
Cracks in 1 in. thick welds in 15 Cr-35 Ni (Type HT) castings have been encountered in each of 24 test plates welded by four foundries using a variety of techniques and electrodes. The groove design of the cast plate is considered very satisfactory as a means of evaluating the welding variables in a test programme, or as a means of qualifying welding procedures and the weldability of materials. Tensile tests on a few transverse-weld specimens gave ultimate strengths of 40,000 to 45,000 lb. per sq. in. at 1400 deg. F. and 17,000 to 21,000 lb. per sq. in. at 1800 deg. F. with fractures occurring sometimes in the weld and sometimes in the base metal. (Author's Abstract.)

WELDABILITY.—Ferrous.—Stainless Steel

1575. LINNERT, G. E.
Corrosion-free stainless welds
Welding Eng., vol. 37, 1952, Jan., pp. 51-53
Extra low carbon stainless steel may be used for welded structures without any risk of subsequent intergranular corrosion, but should not be used if the service temperature is above 800 deg. F. The author deals briefly with their mechanical properties in the plain and as-welded condition.

1576. THIELSCH, H.
Stainless steel weld deposits on mild and alloy steels
Welding J., vol. 31, 1952, Jan. Supp., pp. 37-64
Review of published and unpublished information on dissimilar-metal joints made with stainless steel electrodes; metallurgical characteristics of joints, dilution, mechanical properties, heat treatments, carbon migration, base-steel and weld metal cracking, hardenable steels and applications. (Author's Abstract.)

WELDABILITY.—Non-Ferrous.—Aluminium Bronze

1577. GARRIOT, F. E.
Welding iron-bearing alpha aluminium bronze
Welding J., vol. 31, 1952, Jan., pp. 18-28
This new copper base alloy combines good mechanical properties with excellent weldability. The mechanical properties remain high at sub-zero temperatures and the weld deposits have good strength and high ductility and a fine grain structure. A.S.M.E. approval has been obtained for this alloy of the composition copper, 88·0 to 92·5 per cent.; aluminium, 6·0 to 8·0 per cent.; iron, 1·5 to 3·5 per cent.; others 0·5 per cent. maximum, and a table of design stresses for various temperature ranges is included. The author describes the ring tests carried out to determine the best electrode or filler rod composition using the carbon arc, metal arc, inert-gas-shielded metal arc, inert-gas-shielded consumable electrode, and the submerged arc processes. The procedure to be followed when using these processes is discussed and recommended joint preparations are given. The use of this alloy in mechanical engineering is described and it is stated in conclusion that the alloy can be satisfactorily welded by all the electric arc processes, but that gas welding has so far proved unsatisfactory, due to the absence of a suitable flux. The mechanical properties and corrosion resistance of the weld metal are equal to those of the base metal.

WELDABILITY.—Non-Ferrous.—Light Alloys

1578. HOULDCROFT, P. T.
Progress in welding light alloys
Metallurgia, vol. 45, 1952, Feb., pp. 81-84
The introduction of the argon arc process was an important step forward in welding the light alloys, and the development of the consumable electrode process promises to be of equal significance. The author notes that there are two distinct types of this latter process, the controlled and the self-adjusting arc. In the latter process, current densities of the order of 100,000 amps. per sq. in. and wire feeds up to 400 in. per min. are employed. The high current densities make the arc self adjusting by causing a variation in the burn-off rate with varying arc length, and cause the spray of metal to leave the end of the wire with sufficient velocity to permit welding in all positions. Reference is made to the Aircomatic process and to equipment developed by B.W.R.A. and to the improved aluminium-magnesium alloys available.

WELDED CONSTRUCTION.—Agricultural Machinery

1579. SPENCER, C.
Assembly of agricultural implements
Welding & Metal Fab., vol. 20, 1952, Mar., pp. 91-94
Deals briefly with the application of welding to agricultural implements.

WELDED CONSTRUCTION.—Automobiles

1580. ANON.
Building Jaguar sports cars
Welding & Metal Fab., vol. 20, 1952, Feb., pp. 44-48
Describes the construction of the body unit XK 120 with particular reference to the welding and jigging equipment in use, in a plant capable of producing 12 bodies per hour.

WELDED CONSTRUCTION.—Chemical Plant

1581. ANON.
Fabrication of chemical plant
Welding & Metal Fab., vol. 20, 1952, Mar., pp. 82-90
Deals with the fabricating and welding equipment of a large Midland firm and describes some of its products, including equipment for the chemical and food industries, hot dip galvanising, heat treatment and brewing plant and road and rail tankers.

WELDED CONSTRUCTION.—Design

1582. MIKULAK, J.
Product design for welding
Welding J., vol. 31, 1952, Jan., pp. 29-34
The author lists the fundamentals of economical designing and notes that automatic welding equipment can be used on comparatively short production runs. He describes the application of the principles laid down to drawing office procedure and shop equipment and gives examples of the use of automatic welding equipment and positioners.

WELDED CONSTRUCTION.—Pipes

1583. ANON.
Manufacture of large diameter pipe
Welding & Metal Fab., vol. 20, 1952, Feb., pp. 49-53
This article describes an American plant which produces up to 6 miles of welded pipe per day in O. D. varying from 26 in.-36 in. and in wall thicknesses from ¼ in.-½ in. The pipe is made to a tolerance of ± 1 per cent. of the nominal size and to conform to A.P.I. specification 5LX. The steel used has a composition C, 0·3 per cent., Mn, 1·25 per cent., and is welded by the submerged arc process using a tandem arc system in which two arcs are used, one A.C. the other D.C. spaced 1½ in. apart. The pipe is welded from both the outside and inside, outside first. The as-welded diameter is made slightly smaller than nominal and the pipe is subsequently expanded by hydraulic pressure to the correct size in special dies.

1584. AULER, E. P.
Application of oxy-acetylene processes in pipe fabrication
Industry & Welding, vol. 24, 1951, Dec., pp. 34-36 & 78-80
The use of the oxy-acetylene torch in preparation and heat treatment is briefly described.

1585. BINDEMAN, H. L. and HOOPES, L. N.
"Permanent" pipe lines for liquid food products
Welding Eng., vol. 37, 1952, Jan., pp. 48-50
Pipe for conveying liquid food products must have perfectly clean smooth bores. The author describes the oxy-acetylene welding of thin stainless steel tubing and a small grinding head which is used for cleaning up the inside of the welds and with which it is possible to grind welds between two 20 ft. lengths of pipe. It is stated in conclusion that bacterial contamination has been reduced by using welded pipes compared with the older method of cleaning removable pipes.

WELDED CONSTRUCTION.—Repairs

1586. CLASON, B.
Keeping tractors in service
Welding Eng., vol. 36, 1951, Aug., pp. 26-29
A submerged-arc welding head in conjunction with a motor driven positioner carries out automatic hardfacing of tractor rollers and idler wheels. On rollers the rod is a mild steel tube containing the alloying elements, chromium, molybdenum, vanadium, etc., and on the idlers a chrome-vanadium steel wire is used. The rod is arc deposited at 30 in. of bead per minute and as many as six passes are used on badly worn rollers. No subsequent grinding is necessary. (M. R.)

WELDED CONSTRUCTION.—Tanks

1587. BOTT, H. B.
Monel tanks for boats
Welding Eng., vol. 37, 1952, Jan., pp. 33-35
The author deals briefly with the fabrication of Monel sheet from 0·037 to 0·062 in. thick by the metal arc, inert-gas-shielded arc, gas and resistance processes. Details of jigs for use with the arc and gas processes are shown.

OBITUARY

SIR JAMES LITHGOW, Bt., G.B.E.

Action more than any word in the vocabulary describes the character of Sir James Lithgow, Bt., whose death at the age of 69 in February this year was a heavy personal loss to shipbuilding and associated industries. He was a man of action in every sense of the word whether in the field of battle—he served in the first world war and won the M.C.—or in tackling as he did the many problems that beset the complex industries of shipbuilding, steelmaking and engineering.

To the Institute of Welding, of which Sir James was an Honorary Member and sometime a Vice-President, he was best known for the major part he played in extending the use of welded construction in mercantile shipbuilding when during the war he held the onerous position of Controller of Merchant Shipbuilding and Repairs. In that capacity he had the unusual honour for a civilian of being a member of the Board of Admiralty.

During those long, difficult years, Sir James served the nation well, and it is a tragic coincidence that the Director of Merchant Shipbuilding and Deputy Controller, Sir Amos Ayre, predeceased Sir James by six weeks. These two outstanding shipbuilders, so different in many respects, made the perfect wartime team. Their initiative in leading the shipbuilding mission to America early in the war was the prelude to Henry Kaiser and other distinguished American industrialists embarking on the colossal U.S. merchant shipbuilding programme between 1942 and 1945, the crowning achievement to date of welding applied to shipyard work.

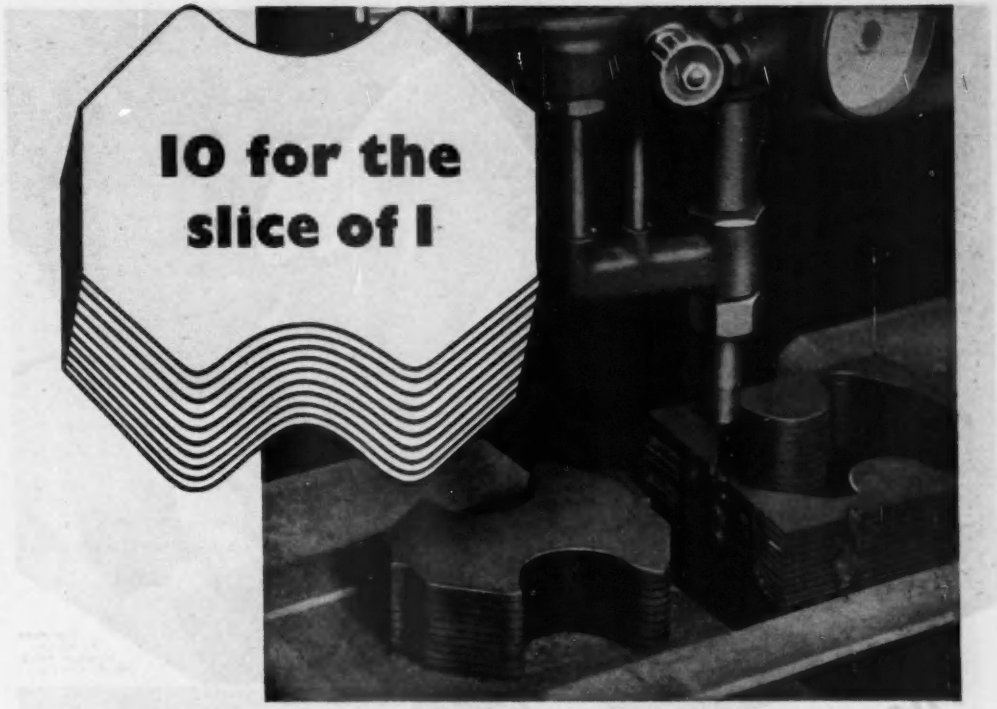
For the best part of forty years James Lithgow was a figure of some magnitude in industry. At the age of twenty-five he had to assume heavy responsibilities in operating with his late brother, Henry, the large merchant-tonnage producing shipyards on the Clyde which they had inherited from their father, W. T. Lithgow, founder of the family's industrial enterprise. Instead of resting on the laurels of the generation before them, the two brothers enhanced their place in shipbuilding and extended it to steelmaking, engineering and associated industries.

Sir James was a champion of integrated, efficient industrial development, and in many ways he set the pattern of Clydeside industry as it is to-day and did much to encourage new enterprises and a wider range of activities for that great area.

He had a rich and unique sense of humour and, like Bernard Shaw, would often say exactly the opposite to what he meant. He had an eye to the long-term view, and anyone who had a worthwhile proposition to put to him was invariably sure of a good hearing from Sir James. No man since the first world war did more than James Lithgow to strengthen industrial Scotland, and many of his acts in that direction, like his generous gifts to charities—running to hundreds of thousands of pounds—were done without the remotest desire for personal reward or publicity. Deeds always took priority over words in the life and career of this truly great man.

D. S. WATT.

We regret also to announce the death of Mr. J. M. Baxter, Member, West of Scotland Branch, and Mr. A. G. Walker, Member, Liverpool Branch.



by B.O.C *oxygen cutting machine*

Ten plates of mild steel cut and shaped in a single pass of the oxygen cutter . . , to identical measurements and with such a high quality finish that no subsequent machining is required. This operation — simple routine to the B.O.C 36" cutter illustrated — saves time, labour and cutting gases, and permits quantity production to be carried on without loss of accuracy. *Apply to our local office for demonstration.*

MAKE AND MEND WITH B.O.C MATERIALS, EQUIPMENT, SERVICE

THE BRITISH OXYGEN CO LTD

LONDON & BRANCHES

Top photo by courtesy of manufacturers, Metallisation Ltd.

The economic fuel for metal spraying

Building up a worn bearing surface by bronze spraying.

Parts recovery and metallic coating by the metal spraying process are only two of the ever-widening range of industrial applications of PYROGAS.

PYROGAS is cheap, and being a liquefied gas results in extremely low cylinder handling costs because, for instance, a 42-lb cylinder produces 350 cu. ft. of fuel gas.

With slight modification, existing metal spraying equipment can be used with PYROGAS.

★ *We should be glad to arrange a demonstration at your works.*

PYROGAS **PYROGAS**

BRITISH CUTTING GASES LTD.

HEAD OFFICE: DOWNSHIRE HOUSE, ROEHAMPTON LANE, LONDON, S.W.15

PUTney 7742 PYROGAS, PUT, LONDON

BRANCHES

BIRMINGHAM · GLASGOW
LONDON · MANCHESTER
SHEFFIELD · SUNDERLAND
SOUTHAMPTON (LYMINGTON)
THORNABY-ON-TEES

Associated Companies

BRITISH GAS AND TORCH CO. LTD.
RAINVILLE ENGINEERING CO. LTD.

TRANSACTIONS OF THE INSTITUTE OF WELDING

VOLUME 14, 1951

Published by THE INSTITUTE OF WELDING

2, Buckingham Palace Gardens, Buckingham Palace Road, London, S.W.1.

PAGE INDEX—The following list shows the pages contained in each issue of the Transactions for 1951:—

pp. 1-23 February
pp. 24-63 April
pp. 64-103 June
pp. 104-151 August
pp. 152-186 October
pp. 187-222 December

AUTHOR AND TITLE INDEX

This index includes in one alphabet the names of authors and speakers in discussions, the titles of papers and the subjects of notes. A name which is not followed by a title is that of a contributor to a discussion or of a person mentioned in a news item.

Subject	*Page*
Abbey Works, Port Talbot—Continuous welded structures	28-38
disc.	38-43
see also Margam Abbey	
Acetylene—A review of the processes for production from hydrocarbons	93
Acetylene—Handling under pressure in chemical reactions	93
Acetylene, The properties and handling of liquid	93
Aircraft—Recent advances in the technique of electric spot welding of aluminium alloys in the French aircraft industry	110-120
disc.	169
Aircraft, Welding on gas turbine engines for	85-91
disc.	173-5
All-welded plate web girder	210
Aluminium alloys in the French aircraft industry, Recent advances in the technique of electric spot welding of	110-120
disc.	169
Aluminium magnesium alloys, Recent French studies on the weldability of	140-4
disc.	172
Aluminium, British experience in the argon arc welding of	121-139
disc.	169-172
American Society for Metals, Congress, October 1951	65
American Welding Society, new President	188
AMBON, W. T.	2
Analysis, Standard methods of (book review)	6
Anglo-American Productivity Team on Welding, report	152, 191, 201-9
Applications and developments with resistance welding	66
Arc welding electrodes, The uses and abuses of	1, 45-52, 190
disc.	52
Arc welding plant, Principles, design and operation of	190
Argon arc welding of aluminium, British experience in the	121-139
disc.	169-172
Argon arc welding, Recent developments in	66-7
Ashurst Hill Summer School of Welding, July 1952	188
Associazione italiana di Metallurgia, Conference September, 1951	65
ATKINS, W. S., Continuous welded structures, Abbey Works, Port Talbot	28-38
disc.	38-43
ATKINS, W. S., and LEWIS, E. M., Developments of design and fabrication in recent British structures	74-84
disc.	175-6
Atomic hydrogen, Chain welding by	58
Austenitic steels, Recent developments in the metallurgy and weldability of the	4
Automatic welding	27
BAILEY, SIR DONALD	170, 175, 176
BAKER, J. F.	167
Battelle International Institute	148
BERRIDGE, P. S. A.	22, 39-40
BIERS, H., and others, Powder processes, a new industrial tool	154-9
disc.	160
BINSTEAD, W. V., and WEST, E. G., British experience in the argon arc welding of aluminium	121-139
disc.	169-172
BISHOP, E., Recent developments in the metallurgy and weldability of the austenitic steels	4
BLAKEBOROUGH, E., Welded fabrications	27
BONDY, O.	23
Book reviews—	
Metallurgical thermochemistry	192
Philips' practical welding course	23
Progress in metal physics	193
Standard methods of analysis	67

Subject	Page
Boyd, G. M.	58, 108-9, 207
Braithwaite, R. G.	22
Bridges and hangars in Spain, Welded	13-21, disc. 22-3
British Acetylene Association—	
Historical notes	94
Jubilee meeting and meeting of the C.P.I., July, 1951	24, 64, 92-4
Report of proceedings	144
British experience in the argon arc welding of aluminium	121-139, disc. 169-172
British Oxygen Co. Ltd.—	
Welding Prize, 1950 awards	65
Welding Prize, 1951	65
British Standards Institution, Publication of standards—	
1507/1508: 1950—Steel pipes and tubes for pressure vessels for use in the mechanical and allied industries	25
1663:1950—Higher tensile steel chain (electrically welded)	25
642: 1951—Calcium carbide (graded sizes)	189
1113: 1951—Water tube boilers and their integral superheaters	65
1719: 1951—Classification of covered electrodes	65
1723: 1951—Brazing	65
1724: 1951—Bronze welding by gas	189
British Welding Research Association—	
Ashorne Hill Summer School of Welding	188
Transactions Research Supplement	2, 25, 65, 153
Brittle fractures—Report of Commission No. 12 of the International Institute of Welding, July, 1951	215
Buckle, L. G.	208
Bulleid, O. V. S.	25
Burford, E. F.	57
Burford, E. F., Design of welded pressure vessels	26-7
Bushell, R., Applications and developments with resistance welding	66
Cambridge University, Post-graduate courses in theory of structures and strength of materials	101
"Can it be welded?"	66
Capacitor, Power factor correction by	26
Carter, W. G.	40-2
Casting versus welding (discussion)	27
Chain Testers' Association of Great Britain	58
Chain welding by atomic hydrogen	58
Clark, A. M., The properties and handling of liquid acetylene	93
Clark, F., Welding reminiscences—1916 to the present day	67
Commission permanente internationale de l'Acétylène—	
Meeting in London, July, 1951	24, 64, 92-4
Report of proceedings	144
Continuous welded structures, Abbey Works, Port Talbot	28-38, disc. 38-43
Control of cracking in the metal arc welding of high tensile structural steels (discussion on paper published in *Welding Research*, August, 1951)	167-8
Control, testing and measuring of welds—Report of Commission No. 5 of the International Institute of Welding, June, 1950	8-9
Report of sub-commission on fatigue of welded structures, July, 1951	214
Corrosion of buried metals, symposium	153
Cottrell, C. L. M.	173, 176
Cottrell, C. L. M., and others, The control of cracking in the metal arc welding of high tensile structural steels (discussion on paper published in *Welding Research*, August, 1951)	167-8
Cracking in the metal arc welding of high tensile structural steels, Control of (discussion on paper published in *Welding Research*, August, 1951)	167-8
Cruickshank, D. D.	40
Davenport, G.	66
Davenport, G., Notes from my welding experiences (repairs to road vehicle chassis and ship repair work)	3
Davies, D. J.	40
Design and fabrication in recent British structures, Developments of	74-84, disc. 175-6
Design of welded pressure vessels	26-7
Deutscher Verband für Schweisstechnik, conference, June 1951	65
Development and progress of machine welding in Britain	3
Developments of design and fabrication in recent British structures	74-84, disc. 175-6
Discombe, E. H.	188
Distortion in the welding of mild steel	26
Dixon, H. E.	169
Documentation—Report of Commission No. 4 of the International Institute of Welding, July, 1951	177-9
Dorman, Long & Co. Ltd.	25
Dorrat, J. A., Report of the Anglo-American Productivity Team on Welding	201-2
Education *see* Post-graduate courses	
University engineering courses	
Efficiency in steel consumption	221
see also Steel saving	
Electric arc welding—Report of Commission No. 2 of the International Institute of Welding, June, 1950	6-7
July, 1951	211-2
Electrical engineering industry, Preparation and welding of fabricated structures for the	191
Electrodepositors' Technical Society	188
Electrodes (arc welding), The uses and abuses of	45-52, 190, disc. 52
Elliott, A. J.	57
Elsworth, E. J. A., A guide to gas cutting and welding in the agricultural industry	65
Evans, E. Ll., and Kubaschewski, O., Metallurgical thermochemistry (book review)	192
Eyes, Protection during welding operations	190
Faguet, J., Recent advances in the technique of electric spot welding of aluminium alloys in the French aircraft industry	110-120, disc. 169
Fatigue testing and fatigue testing machines—Report of Commission No. 13 of the International Institute of Welding	11-12
Ferguson, H., Power factor correction by capacitor	26
Films *see* Welding films	
Finnart pipeline	2
Firth (Thos.) and John Brown Ltd. (works visit)	191
Fitch, I. C., The uses and abuses of arc welding electrodes	45-52, 190, disc. 52
Award of Sir William J. Larke Medal for 1950	1
Flintham, E.	63
Forge, Machine-cutting in the	145-8
Foulkes, R. A.	175-6
Fowler, R. J.	63, 209
France—Société française de Métallurgie, conference, 1951	65
French aircraft industry, Recent advances in the technique of electric spot welding of aluminium alloys in the	110-120, disc. 169
French studies (recent) on the weldability of aluminium magnesium alloys	140-4, disc. 172
Fuchs, E.	208

Subject	Page
FUCHS, E., Safety in the practice of welding (*Trans.*, June, 1950, pp. 87-94)—Correction	2
FUCHS, E., The status of the welding engineer	55-6, 58
LE GALL, J.	110, 169
Gas turbine engines for aircraft, Welding on	85-91
disc.	173-5
Gas turbines for use on land, Welding in relation to	68-73
disc.	173-5
Gas welding and allied processes—Report of Commission No. 1 of the International Institute of Welding, June 1950	5-6
July, 1951	177
GEERLINGS, H. G.	175
Germany—Deutscher Verband für Schweisstechnik, conference, 1951	65
Girder, All-welded plate web	210
GOTTFELDT, H.	22, 176
GOWLAND, G. S.	209
GRANJON, H.	140-4, 172
GRIFFIN, A. E., Production welding	27
GRIFFITHS, S. H.	63
GRIFFITHS, S. H., Report of the Anglo-American Productivity Team on Welding	204-5
HALE, A. L.	172
Handling acetylene under pressure in chemical reactions	93
Hangars and bridges in Spain, Welded	13-21
disc.	22-3
Hardfacing	26
HARMAN, M. C.	208
HARVEY, A. A. B.	52
HAWKINS, E.	23
HERENGUEL, J., and HOLLARD, M., Recent French studies on the weldability of aluminium magnesium alloys	140-4
disc.	172
Hill (C. W.) Prize, 1950	2
1951	65, 152
HILL, H. V.	2, 23
HIPPERSON, A. J.	174
HIRSCHMANN, F.	169-170
History of Welding—Seventy years of welding	195-200
Welding reminiscences—1916 to the present day	67
HODDLE, A.	144
HODDLE, A., British Acetylene Association Jubilee, 1901-1951	94
HODGES, L., Machine cutting in the forge	145-8
Award of the B.O.C. Welding Prize, 1950	65
HOLLARD, M., and HERENGUEL, J., Recent French studies on the weldability of aluminium magnesium alloys	140-4
disc.	172
HOOKER, A. V. R.	39, 167-8
HOULDCROFT, P.	171
HOUSTON, A. V., Distortion in the welding of mild steel	26
Hydrocarbons, A review of the processes for production of acetylene from	93
Hygiene and safety—Report of Commission No. 8 of the International Institute of Welding, June, 1950	10-11
July 1951	180-1
INSTITUTE OF WELDING—	
Abstracts from recent welding literature	99-101, 149-150, 184-5, 218-221
(*see also* Latest Additions to the Library)	
Anglo-American Productivity Team on Welding, report	152, 191, 201-9
Annual General Meeting, July, 1951	106-9
Annual luncheon, January, 1952	187
Appointment of Technical Assistant	25
Armorial window, gift of Mr. C. S. Milne	188
Ashorne Hill Summer School of Welding	188
Associate-Membership Examination, January, 1951—results	65
Branch activities	3-4, 26-7, 63, 66-7, 190-2
Birmingham	4
East Midlands	26
East Scotland	3, 26, 190
Leeds	3
Liverpool	3, 66, 190, 192
Manchester	1, 3, 26, 66-7, 191
Preston	27
Sheffield	3, 191
Southampton	3
South London	1, 67
South Western	3, 67
Tees-side	27, 67, 191
Tyneside	3
West of Scotland	109
Wolverhampton	4, 27, 191-2
British Officers of the International Institute of Welding	106
Competitions—	
B.O.C. Welding Prize, 1950, awards	65
B.O.C. Welding Prize, 1951	65
C. W. Hill Prize, 1950, awards	2
C. W. Hill Prize, 1951	65, 152
International Photographic Competition	189
Sir William J. Larke Medal, 1950, award	1
Sir William J. Larke Medal, 1952, revised regulations	106, 188
Spanish Institute of Welding, 3rd Welding Competition	2, 65
Council elections, 1951	24
Gift of film by Messrs. Dorman, Long & Co. Ltd.	25
Gift of armorial window by Mr. C. S. Milne	188
Handbook for welded structural steel, proposed new edition	153
Honorary Officers and Council, 1951-52	107
Institute meetings—	
1951-52 programme	64, 187
September and October, 1951	107
December, 1951, and January, 1952	186
February and March, 1952	222
Institute membership	103, 109, 193
Institute Notes and News	1-2, 24-5, 64-5, 106, 108-9, 152-3, 187-9
International Welding Congress, 1951	1, 24, 64, 104-6, 189
Latest additions to the Library	12, 62-3, 102, 151, 183-4, 216-7
Overseas conferences	65, 189
Plymouth Section	65
Resignation of Mr. A. O'Neill	188
Spring meeting, 1952	152, 187
Symposium on notch bar testing	153, 188
Transactions, reprints available	2
Transactions Research Supplement restricted circulation	2, 25 65, 153
Welding films	25, 153
Welding in university courses	65, 101, 153
Working Reserve Fund	1, 25
names of contributors	194, 210
International Fair, Liege, 1952	189
International Institute of Welding—	
International Welding Congress, July, 1951	1, 24, 64, 189

Subject	Page
Report of proceedings	104-6
Papers read at the Congress—	
1st session—Control of cracking in the metal arc welding of high tensile structural steels, discussion only	167-8
Possibilities of the pre-stressing of metallic constructions	161-7
disc.	167
Powder processes, a new industrial tool	154-9
disc.	160
2nd session—British experience in the argon arc welding of aluminium	121-139
disc.	169-172
Recent advances in the technique of electric spot welding	110-120
disc.	169
Recent French studies on the weldability of the aluminium magnesium alloys	140-4
disc.	172
3rd session—Developments of design and fabrication in recent British structures	74-84
disc.	175-6
Welding in relation to gas turbines for use on land	68-73
disc.	173-5
Welding on gas turbine engines for aircraft	85-91
disc.	173-5
Reports of Commissions, June 1950	5-12
July 1951	177-182, 159, 211-5
Italy—Associazone italiana di Metallurgia, conference, 1951	65
JACKSON, M. D., and others, The control of cracking in the metal arc welding of high tensile structural steels (discussion on paper published in *Welding Research*, August, 1951)	167-8
JENKINS, R., Report of the Anglo-American Productivity Team on Welding	203-4
JOHNSON, Mr., Site radiography	67
JONES, D. G.	66
JUKES, F.	63
KELLY, C. J., The re-design of a plate girder	59-61
Award of the C. W. Hill Prize for 1950	2
KENNETT, S. J., Metallurgy for welders	3
KERR, D. M., The status of the welding engineer	55, 58
KERSHAW, A. C.	57
KINZEL, A. B., and others, Powder processes, a new industrial tool	154-9
disc.	160
KUBASCHEWSKI, O., and EVANS, E. LL., Metallurgical thermochemistry (book review)	192
LANCASTER, J. F.	57, 171
Land turbines *see* turbines	
LARDGE, H. E.	52
LARDGE, H. E., Report on the work of the Anglo-American Productivity Team on Welding	191, 202-3
LARDGE, H. E., Welding on gas turbine engines for aircraft	85-91
disc.	173-5
LARKE, SIR WILLIAM J.	108-9, 189
Larke Medal for 1950, award	1
Larke Medal for 1952, revised regulations	106, 188
LEATHERDALE, C. E.	2
LEWIS, E. M., and ATKINS, W. S., Developments of design and fabrication in recent British structures	74-84
disc.	175-6
Liege International Fair, 1952	189
LLEWELLYN, D.	4
Machine-cutting in the forge	145-8
Machine welding in Britain, Development and progress of	3-4
Magnesium aluminium alloys, Recent French studies on the weldability of	140-4
MANKTELOW, A. G.	57
Margam Abbey Steelworks (film)	35
MARSHALL, Mr.	4
MARTIN, Mr.	57
MARTIN, H.	109
MCPHERSON, D. H., All-welded plate web girder	210
MCWILLIAM, J. A.	26
Metal arc welding of high tensile structural steels, Control of cracking in	disc. 167-8
Metal physics, Progress in (book review)	193
Metallic constructions, Possibilities of the pre-stressing of	161-7
disc.	167
Metals—Symposium on corrosion of buried metals	153
Metallurgical thermochemistry (book review)	192
Metallurgy and weldability of the austenitic steels, Recent developments in the	4
Metallurgy for welders	3
Metallurgy, Welding	190-1
MILLER, S. A., Handling acetylene under pressure in chemical reactions	93
MILNE, C. S.	108-9, 189, 192, 207
MILNE, C. S., Illustrations to Presidential Address (*Trans. Inst. Welding.*, Dec., 1950, 167-8,173)	95-8
MITCHELL, E. J., "Can it be welded?"	66
MOORE, E. C., The status of the welding engineer	53-4, 58
MOSS, A. R.	57, 109
NEWPORT, F., Introduction to the calcium carbide industry	93
Notch bar testing—Symposium on recent developments in notch bar testing and their relation to welded construction	153, 188
Notes from my welding experiences (G. Davenport)	3
OBITUARY—Mr. W. T. Tolhurst	221
ORTON, L. H.	170-1
PARKIN, N.	27
PARSLOE, G.	57, 189
PATERSON, J. H., The status of the welding engineer	52, 53, 58
Philips Electrical Ltd., Philips' practical welding course (book review)	23
Pipelines, The Finnart pipeline	2
see also Steel saving by welding	
Plate girder, The redesign of a	59, 61
POOLE, H.	209
Possibilities of the prestressing of metallic constructions	161-7
disc.	167
Post-graduate courses at Cambridge University in Theory of structures and strength of materials	101
Powder processes, a new industrial tool	154-9
disc.	160
Power factor correction by capacitor	26
Preparation and welding of fabricated structures for the electrical engineering industry	191
Pressure vessels, welded, Design of	26-7
Prestressing of metallic constructions, Possibilities of	161-7
disc.	167
Principles, design and operation of arc welding plant	190
Production welding	27
Progress in metal physics (book review)	193
Properties and handling of liquid acetylene	93
Protection of the eyes during welding operations	190
PUFAHL, H. R., and others, Powder processes, a new industrial tool	154-9
disc.	160
Radiography, Site	67
Railway rolling stock	44
Recent advances in the technique of electric spot welding of aluminium alloys in the French aircraft industry	110-120
disc.	169

Subject	Page
Recent developments in argon arc welding	66-7
Recent developments in notch bar testing and their relation to welded construction	153, 188
Recent developments in the metallurgy and weldability of the austenitic steels	4
Recent French studies on the weldability of aluminium magnesium alloys	140-4
	disc. 172
Re-design of a plate girder	59-61
Reeks, C., Site radiography	67
Reeve, H. H., The preparation and welding of fabricated structures for the electrical engineering industry	191
Reisser, S. M.	109
Reisser, S. M., Report of the Anglo-American Productivity Team on Welding	201
Repairs to road vehicle chassis (Notes from my welding experiences—G. Davenport)	3
Repairs *see also* Ship repair work	
Research—Formation of the Battelle International Institute	148
Residual stresses and stress relieving—Report of Commission No. 10-11 of the International Institute of Welding, July, 1951	182
Resistance welding, Applications and developments with	66
Resistance welding—Report of Commission No. 3 of the International Institute of Welding, July, 1951	212-4
Review of the processes for production of acetylene from hydrocarbons	93
Riddihough, M., Hardfacing	26
Roberts, Mr.	4
Roberts, R. R.	173-4
Robertson, J. M., Welding in relation to gas turbines for use on land	68-73
	disc. 173-5
Rollason, E. C., Welding metallurgy	190-1
Safety and hygiene—Report of Commission No. 8 of the International Institute of Welding, June, 1950	10-11
Safety in the practice of welding (*Trans. Inst. Welding*, June, 1950, pp. 87-94)—Correction	2
Safety *see also* Protection	
Sankey (Jos.) & Sons Ltd. (works visit)	192
Semper, E. Seymour	206-7
Seventy years of welding (Mr. H. J. Thompson's Presidential Address)	195-200
Shaw, J., Site radiography	67
Ship repair work (Notes from my welding experiences—G. Davenport)	3
Siddle, W.	27
Sillivant, R. R.	160, 171-2, 173
Simmie, W. S., The status of the welding engineer	54-5
Site radiography	67
Smerd, H. O., Modern chain making	58
Smout, Sir Arthur	4
Société française de Métallurgie, conference, October, 1951	65
Soete, W., Possibilities of the pre-stressing of metallic constructions	161-7
	disc. 167
Spain, Welded bridges and hangars in	13-21
	disc. 22-3
Spanish Institute of Welding—Competitions	2
Spence, Mr. Site radiography	67
Spencer, C.	57
Spot welding of aluminium alloys in the French aircraft industry, Recent advances in the technique of	110-120
	disc. 169
Standard methods of analysis (book review)	67
Standardisation—Report of Commission No. 7 of the International Institute of Welding, July, 1951	179-180
Status of the welding engineer (symposium)	53-8
Steel consumption, Efficiency in	221
Steel Economy Committee, 4th Report, October, 1950	44
Steel (mild), Distortion in the welding of	26
Steel saving by welding	44
Steels (austenitic), Recent developments in the metallurgy and weldability of the	4
Steels—Control of cracking in the metal arc welding of high tensile structural steels	disc. 167-8
Stretton, H. J., Development and progress of machine welding in Britain	3-4
Structures, Developments of design and fabrication in recent British	74-84
	disc. 175-6
Swan, D., and others, Powder processes, a new industrial tool	154-9
	disc. 160
Swan, W., Automatic welding	27
Taylor, G.	77
Taylor, H. G.	152, 175
Taylor, H. G., Report of the Anglo-American Productivity Team on Welding	205-6
Terminology—Report of Commission No. 6 of the International Institute of Welding, July, 1951	179
Testing, control and measuring of welds—Report of Commission No. 5 of the International Institute of Welding, June, 1950	8-9
Report of sub-commission on fatigue of welded structures, July, 1951	214
Thermodynamics *see* Metallurgical thermochemistry	192
Thomas, J. R.	63
Thomas, J. R., The status of the welding engineer	56-7, 58
Thompson, Howard J.	52, 109, 160, 201, 209
Thompson, Howard J., Seventy years of welding (Presidential Address)	195-200
Thompson, J. H. N., Manufacturing times for welded products	191-2
Time study—Manufacturing times for welded products	191-2
Torroja, E., Welded bridges and hangars in Spain	13-21
	disc. 22-23
Turbine (gas) engines for aircraft, Welding on	85-91
	disc. 173-5
Turbines (gas) for use on land, Welding in relation to	68-73
	disc. 173-5
United States—	
American Society for Metals, conference, 1951	65
American Welding Society, new President	188
United Steel Companies Ltd., Standard methods of analysis (book review)	67
University engineering courses, Welding in	65, 153
see also Cambridge University	
Uses and abuses of arc welding electrodes	1, 45-52, 190
	disc. 52
Vehicle chassis repairs by welding (Notes from my welding experiences—G. Davenport)	3
Warley, J.	40, 42-3
Weck, R.	23, 43
Weldability—"Can it be welded?"	66
Weldability of aluminium magnesium alloys, Recent studies on the	140-4
	disc. 172
Weldability—Report of Commission No. 9 of the International Institute of Welding, July, 1951	181-2, 214-5
Welded bridges and hangars in Spain	13-21
	disc. 22-3
Welded fabrications	27
Welded pressure vessels, Design of	26-27

Subject	*Page*
Welded structures (continuous), Abbey Works, Port Talbot	28-38
	disc. 38-43
Welding engineer, The status of the (symposium)	53-8
Welding films—	153
Argonarc welding process (B.O.C. Ltd.)	188
Depositing stellite with the oxy-acetylene flame (Deloro Stellite Ltd.)	188
Distillation of crude oil	27
Fabrication and transportion of a flash fractionating column	27
Manipulation of corrosion and heat resisting steels (Firth-Vickers Ltd.)	26
Some applications of Firth-Vickers special steels	26
Welded structures—Welding of the Margam Abbey Steelworks (Dorman Long & Co. Ltd.)	25
Welding in relation to gas turbines for use on land	68-73
	disc. 173-5
Welding instruction—Report of Commission No. 14 of the International Institute of Welding, July, 1951	182, 159
Welding metallurgy	190-1
Welding of mild steel, Distortion in the	26
Welding on gas turbine engines for aircraft	85-91
	disc. 173-5
Welding on the Finnart pipeline	2
Welding reminiscences—1916 to the present day	67
Welding, Steel saving by	44
see also Efficiency	
Welding *versus* casting (discussion)	27
WEST, E. G.	172
WEST, E. G., and BINSTEAD, W. V., British experience in the argon arc welding of aluminium	121-139
	disc. 169-172
Whessoe Ltd. (works visit)	191
WHITMAN, J. G., and others, The control of cracking in the metal arc welding of high tensile structural steels (discussion on paper published in *Welding Research*, August, 1951)	167-8
WILBOURNE, R., A decade with a torch, or Through the tinted glass	65
WILLOTT, W. H., Protection of the eyes during welding operations	190
WILLRICH, H. O.	109
WINTERTON, K.	38, 174
WOOLCOCK, J. W., A review of the processes for production of acetylene from hydrocarbons	93
WOOLLCOTT, W. A., Recent developments in argon arc welding	66-7
Works visits—	
Thos. Firth & John Brown Ltd.	191
Joseph Sankey & Sons Ltd.	192
Whessoe Ltd.	191
WRATE, W. A., Principles, design and operation of arc welding plant	190

Cutting remarks through history...

FIG LEAVES . . BEAU BRUMMEL . . AUSTERITY . . UTILITY . . *and still the Tailor survived! You also can be sure of survival if you use*

. . . cutting blowpipes by

BRITISH INDUSTRIAL GASES LTD.

Head Office: 32 VICTORIA STREET, LONDON, S.W.1

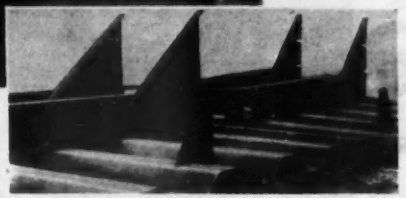
Telephone: **ABBey 6082/3 and 4**

WORKS			
London:	Eastway, Hackney, London, E.9	*Telephone: Amherst 5443/4*
Manchester:	Richmond Road, Trafford Park, Manchester, 17	*Telephone: Trafford Park 1041/2*
Liverpool:	Fleming Road, Speke, Liverpool, 19	*Telephone: Hunts Cross 1212/3*
Glasgow:	Queen Elizabeth Ave., Hillington, Glasgow, S.W.2	*Telephone: Halfway 1651*

Photograph by courtesy of Bartram & Sons Ltd.

Pressed Steel Troughing is used by the leading Shipbuilders in the Tyneside and Clydeside areas.

EGYPT—
The Port Said Engineering Works, Port Said



Large illustration: TRANSVERSE BULKHEAD IN POSITION

Small illustration: BULKHEADS WITH GIRDERS AND WEPS ATTACHED READY FOR ERECTION.

PRESSED STEEL

Troughing

FOR SHIPS' BULKHEADS

Sections of Troughing pressed from Steel Plates are found in actual practice to be superior to the old method of welding steel plates together. Here are six specific advantages:—

● Saves up to 20% steel weight. ● Reduces labour costs. ● No comparative sharp corners to damage cargo. ● Fewer edges where corrosion can begin. ● Smooth surface throughout which is easy to clean, scrape and paint. ● Suitable for transverse, longitudinal and 'tween-deck bulkheads.

Troughing is supplied in lengths up to 30 feet.

MOTHERWELL BRIDGE & ENGINEERING CO. LTD.

Telegrams: BRIDGE, MOTHERWELL
Telephone: MOTHERWELL 40, 41, 42

HEAD OFFICE AND WORKS:
MOTHERWELL

London Address: 82, VICTORIA STREET, S.W.1
Telegrams: MOBRICOLIM, SOUWEST, LONDON
Telephone: VICTORIA 4183

ALICRAFT
HARDCRAFT
STEELCRAFT
FERROCRAFT
BRONZECRAFT

for craftsmen who want the best

Here is an outstandingly good range of oxy-acetylene Welding Rods—ALIcraft for aluminium and alloys, HARDcraft for hard surfacing, STEELcraft for mild steel and iron, BRONZEcraft for bronze-welding. They will give you consistently reliable welds.

Full details and prices are available on request.

WELDCRAFT LTD
PROGRESS WAY · CROYDON · ENGLAND Phone: CROydon 1900 (PBX)

CIRCALINE MARK III

cuts clean circles & lines quickly

The latest "Circaline" oxygen cutting machine is a handy, lightweight sturdy tool for cutting straights, circles, ovals, segments, contours, etc. The valves and controls are mounted upon the aluminium alloy body casting. The burner is the new "split" type with swivel head for bevel cuts. The "Circaline" travels from 3 in. to 27 in. per minute and can run on flexible tracks supplied in 6 ft. sections or on a 6 in. channel.

Hancoxygen cutting is best—write for catalogue to-day.

SEE OUR STAND NO. D739/638, B.I.F. BIRMINGHAM

HANCOCK & CO. (Engineers) LTD.
PROGRESS WAY, CROYDON Telephone: CROYDON 1908

HANCOCK CUTTING MACHINES

Large Tanks

—welded, of course

BUTTERFIELDS fabricate Large Tanks in mild steel and stainless steel in wide variety '— surface and underground petroleum storage tanks, tanks to hold milk or beer, processing and storage tanks for all kinds of industrial liquids.

Examples of Butterfield work will be shown at the British Industries Fair, on Stand No. D.537 (Stainless Steel Plant and Equipment) and on Stand No. A.314 (Galvanised Products).

W. P. BUTTERFIELD LTD.
SHIPLEY, YORKS. LONDON:
AFRICA HOUSE, KINGSWAY, W.C.2

BIF 1952
MAY 5-16
CASTLE BROMWICH
BIRMINGHAM
SEE OUR EXHIBIT

BUTTERFIELDS
The Big Name for Large Tanks

RESEARCH . . .
the Key to Efficiency -

Increased productivity is a first fruit of Research. Without it productivity becomes static, invention is stultified, the industrial race is lost. The Quasi-Arc Company has enjoyed 40 years pre-eminence in Electric Arc Welding, but without a highly qualified research staff constantly at work could not hope to maintain its position in the industry. Q.A. manufacture 31 different types of electrodes, design a large range of arc welding plant, and are sole concessionaires for the newly developed 'Twin-Arc' welding process.

A comprehensive catalogue is available on request

Quasi-Arc

THE QUASI-ARC COMPANY LIMITED
BILSTON, STAFFORDSHIRE

Manufacturers of Electrodes, Plant and Accessories for Manual Arc Welding.

International Welding Congress 1951

The complete Proceedings of the Congress in English are published in the Transactions of the Institute of Welding for June, August and October, 1951. Included are the texts of eight papers, reports of the discussion at the Open Sessions, and the Reports of the Chairmen of the Technical Commissions, with a General Report on the Congress.

Subjects of the Open Sessions are Welding of Bridges and Structures, Welding of the Wrought Light Alloys, and Recent Developments in British Welding.

Copies of the three issues obtainable, price 20s., post free from
THE SECRETARY, THE INSTITUTE OF WELDING,
2, BUCKINGHAM PALACE GARDENS, LONDON, S.W.1

Essential for the Works Library

BIBLIOGRAPHICAL BULLETIN FOR WELDING AND ALLIED PROCESSES

Published by the International Institute of Welding.

This is the only work in existence which provides systematically classed and up-to-date abstracts of welding literature published throughout the entire world.

The Bulletin is printed in English and French and appears quarterly. Each number contains approximately 600 abstracts. There is an annual index of authors.

Special annual subscription (4 numbers). Members of the Institute of Welding, £3 5s. 0d. Ordinary annual subscription, £4 16s. 0d.

The World's Welding Knowledge for 16/3 a Quarter.

Orders to:—
THE INTERNATIONAL INSTITUTE OF WELDING,
2, Buckingham Palace Gardens,
London, S.W.1

S T O P

and
consider
CYC-ARC
Stud-welding
advantages!
NO drilling, tapping,
perforation!
GREATER output,
LOWER costs!
British Railways
(Scottish Region) used
Cyc-Arc Stud-welding
to attach bearings,
brackets, levers,
boxes, etc., etc.,
by means of ¾"
and ⅝" dia. studs
to this 43 ft.
tubular pole.

(Photograph by courtesy of British Railways, Scottish Region)

* * *

CYC-ARC
REG. TRADE MARK

27-29 NEW NORTH ROAD,
LONDON, N.1

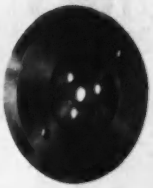
CLErkenwell 3344/8

Visit us at STAND C.218
B.I.F. BIRMINGHAM

ELMET **WELDING MATERIALS**

FOR
ELECTRIC RESISTANCE WELDING

ELMET METALS
in different compositions
FOR ALL WELDING PROBLEMS
in Rods, Bars, Discs and Rings

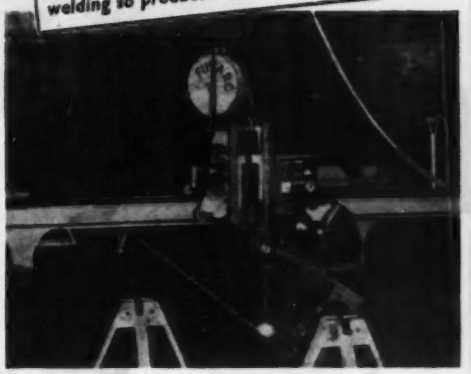


STANDARD
SPOT WELDING
ELECTRODES
*
SEAM WELDING
WHEELS
*
UPSETTING DIES

Further information and quotations supplied on request

METRO-CUTANIT LTD
ASSOCIATED WITH METROPOLITAN-VICKERS ELECTRICAL CO. LTD.
160 PICCADILLY LONDON W1
Telephone GROSVENOR 7121

IT IS FUSARC-PLANNED EQUIPMENT which makes mechanised welding so productive . . .



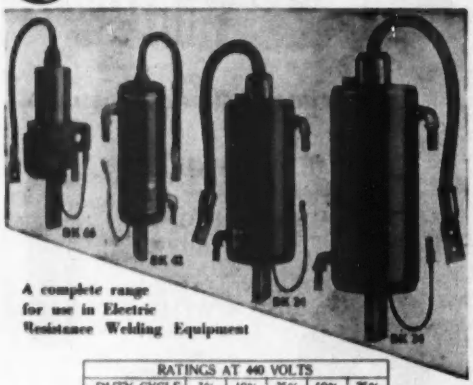
The manufacture of **FRAMES & BEDPLATES** is only one example of a production welding job *planned* by Fusarc. There are scores of other examples in a wide field of work, illustrated in Fusarc Production News Sheets, free copies of which will be sent regularly on request.

FUSARC
MECHANISED WELDING

FUSARC LTD., Team Valley, Gateshead, 11, Co. Durham

IGNITRONS

—HIGH-SPEED HEAVY-CURRENT ELECTRONIC "CONTACTORS"



A complete range for use in Electric Resistance Welding Equipment

RATINGS AT 440 VOLTS					
DUTY CYCLE	5%	10%	25%	50%	75%
IGNITRONS	kVA	kVA	kVA	kVA	kVA
TWO BK 66	300	158	88	44	28
TWO BK 42	600	361	202	110	75
TWO BK 24	1,200	836	475	268	176
TWO BK 34	2,400	1,976	1,100	691	440

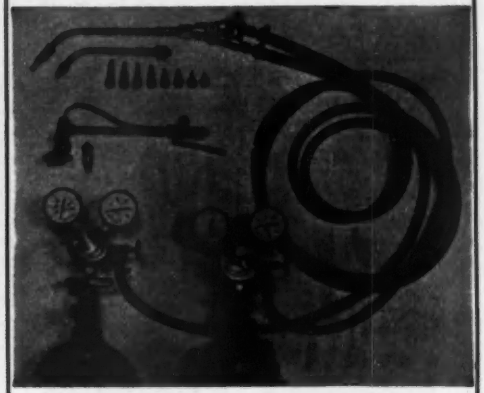
Interchangeable with American Ignitrons sizes A.B.C.D. without modification to your equipment.

THE BRITISH THOMSON-HOUSTON COMPANY LIMITED RUGBY ENGLAND

Member of the AEI group of companies

OUR LATEST PATTERN

WELDING & CUTTING APPARATUS



CATALOGUE ON APPLICATION TO

THORN & HODDLE LTD.,

151, VICTORIA STREET, LONDON, S.W.1

Telephone: VICTORIA 3373 Telegrams: INCANTO, SOWEST, LONDON

This is the welding rod for all round service. It requires little or no preheating and can be used to weld all metals except aluminium. Sifbronze patented copper-zinc alloy rods are better because of their EXTRA constituents.

Write for full details today, also ask for free copy of "Self-Tips" magazine.

SUFFOLK IRON FOUNDRY (1920) LTD

SIFBRONZE WORKS, STOWMARKET, SUFFOLK

Telephone Stowmarket 183 (3 lines)

WELDING PRACTICE

Edited by F. FUCHS AND H. BRADLEY

Vol. 1. WELDING METHODS & TESTS
Price 17*s.* 6*d. Ready now*

Vol. 2. WELDING FERROUS METALS
Price 22*s.* 6*d.*

Vol. 3. WELDING NON-FERROUS METALS
Price 22*s.* 6*d. Ready now*

Set of 3 Volumes, price 55*s.*

This book has been prepared to meet the needs of engineering students and apprentices, designers, draughtsmen, works engineers, inspectors and foremen in charge of welders. It has been regularly used in pamphlet form within the organisation of Imperial Chemical Industries Ltd. The warmth of its reception and its proven usefulness has led to the pamphlets being revised where necessary, brought up to date and published in the present form.

Brochure with full list of contents, post free from

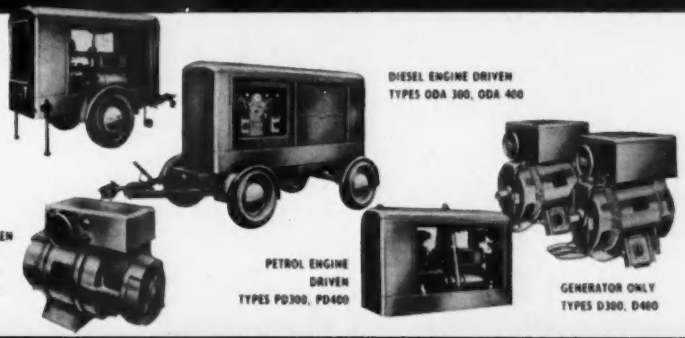
Butterworths Scientific Publications

BELL YARD · TEMPLE BAR · LONDON W.C.2.

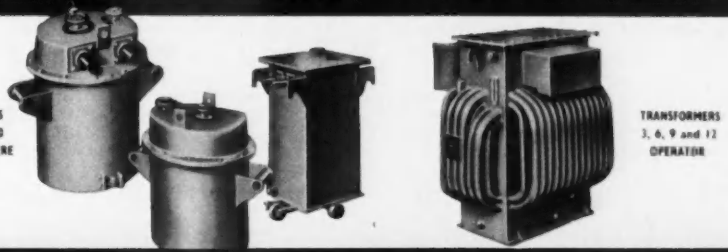
ROCKWELD

Arc welding electrodes for all purposes.
A.C. & D.C. welding plant of all types and capacities.
Welders' Accessories and general supplies for the welding shop.

SINGLE-OPERATOR D.C. ARC WELDING PLANT


PETROL ENGINE DRIVEN TYPE PD250
DIESEL ENGINE DRIVEN TYPES ODA 300, ODA 400
A.C. MOTOR DRIVEN TYPES AD175 AD300 AD400
PETROL ENGINE DRIVEN TYPES PD300, PD400
GENERATOR ONLY TYPES D300, D400

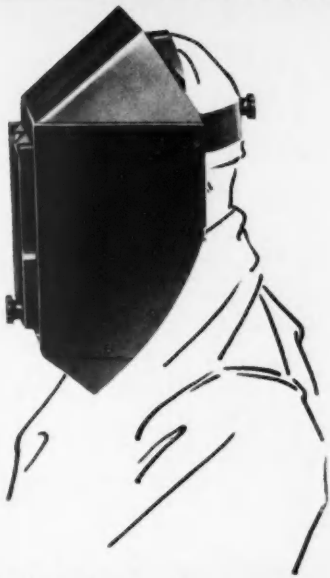
MULTI-OPERATOR A.C. ARC WELDING PLANT

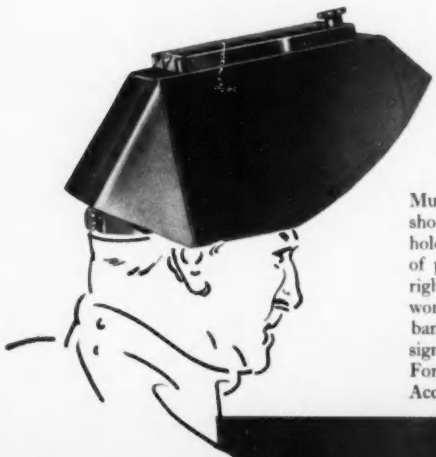


SINGLE-OPERATOR ARC WELDING TRANSFORMERS

Our Engineers are available for advice on the selection, arrangement and installation of these machines.

ROCKWELD LTD · CROYDON · SURREY TEL: CROYDON 7161 (5 LINES) GRAMS: ROCKWELD, PHONE, CROYDON





Murex helmets for electric arc welding are soundly constructed of shockproof laminated plastic and are provided with a patented glass holder which enables the coloured glass to be brought into and out of position in a split second. Thus the welder can sight his work right up to the moment of striking the arc and can carry out other work without wearing goggles. The helmets have adjustable headbands, allowing the welder to have both hands free, and are designed to provide the maximum protection, comfort and ventilation. For full details of these helmets and the whole range of Murex Welding Accessories, please write for Publication No. M.41.

ELECTRIC ARC WELDING

EQUIPMENT & ELECTRODES

A.8

Printed in England by LAWRENCE PRESS LTD., Henry Road, New Barnet, Herts., and Published by The Institute of Welding, 2, Buckingham Palace Gardens, London, S.W.1. *April*, 1952.